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AN INVESTIGATION OF THE OVER WATER ASPECTS OF VTOL AIRPLANES AT HIGH DISC LOADING

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ABSTRACT

Tests, using small scale models of the Curtiss-Wright X-100 and X-19 aircraft, have been carried out to investigate the disturbance and spray caused by VTOL aircraft hovering above water. Full scale disc loadings in the range 20 to 70 lb./sq.ft. were represented. Correlation of the model test results with full scale testing of the X-100 airplane over water at a disc loading of 23 lb.sq.ft. and height of 21 feet show excellent agreement.

Downwash effects on objects floating below the X-19 model were also demonstrated. Spray is shown to rise to considerable heights at the higher disc loadings with the models close to the water surface, and floating objects may be subjected to severe buffeting under these conditions.

LIST OF ILLUSTRATIONS

NOMENCLATURE

A	Propeller Disc Area - sq.ft.
D	Exit Diameter of Nozzle or Propeller Diameter - in. or ft.
h	Maximum Height at which Spray is Observed - in. or ft.
q	Dynamic Pressure - lb./sq.ft.
q_s	Maximum Dynamic Pressure Parallel to Water Surface - lb./sq.ft.
q_n	Mean Dynamic Pressure at Exit of Nozzle - lb./sq.ft.
S	Model Scale Factor - D_F/D_M
T	Total Thrust of Propeller - lb.
T/A	Propeller Disc Loading - lb./sq.ft.
z	Height of Nozzle Exit or Propeller Above Water - in. or ft.
$\beta_{.671}$	Propeller Blade Angle at 0.671 Radius

Subscripts

F	Full Scale
M	Model Scale
O	Condition at which Spray is First Observed

SUBJECT

An investigation of the over-water aspects of VTOL airplanes at high disc loading.

OBJECT

To establish, by means of small-scale powered VTOL model tests, the water agitation and spray characteristics resulting from hovering flight operations of moderate to high disc-loaded propeller-powered VTOL aircraft.

SUMMARY

Correlation of some previous tests of air ducts and fans exhausting over water and some results of tests presented herein, have shown that it is possible to predict full scale spray characteristics from small scale model tests. Accordingly, tests have been carried out with scale models of the Curtiss-Wright X-100 and X-19 aircraft in their hovering configuration over a water tank and the full scale spray characteristics are predicted.

Excellent agreement is shown between the full scale results of the X-100 VTOL airplane tests over water at a disc loading of 23 lb./sq.ft. and height of 21 ft. and the spray height predicted from

model tests for this aircraft, confirming that model tests can be used to determine the spray characteristics for hovering aircraft.

Test results indicate that operation of the X-19 VTOL aircraft above water at disc loading of about 25 lb./sq.ft. will not produce objectionable spray characteristics. (The airplane will be completely above the spray at disc heights above 26 feet.) At disc loadings above 50 lb./sq.ft. and at heights below 30 feet the spray becomes very heavy which may severely hinder over water operations for hovering aircraft at these conditions.

Tests with the X-19 model hovering over scale models of life rafts indicate that at heights below 30 feet above the water, the small one-man raft may be in danger of capsizing. Rescue from such rafts would probably have to be carried out from a height in excess of 16 feet for a four-man life raft and above 30 feet for a one-man raft.

INTRODUCTION

Recently developed propeller driven VTOL aircraft have been designed to operate at relatively high disc loadings (25 to 70 lb./sq.ft.) compared with helicopter disc loadings which are of the order of 10 to 15 lb./sq.ft. Aircraft operating at these high disc loadings over water may cause considerable amounts of spray and water agitation, which could adversely affect the operating environment due to obstruction of vision, engine ingestion and disturbance of objects floating near or beneath the aircraft.

Curtiss-Wright, in cooperation with the Bureau of Naval Weapons, therefore decided to investigate the possibility of predicting the effect of moderate to high disc loadings over water from tests with small scale powered models, and in particular to predict the spray formation and the effects of water agitation on air-sea rescue operations for the full scale X-19 aircraft.

Examination of earlier test work showed that the formation of spray is dependent on the maximum dynamic pressure parallel to the water surface and that spray height is proportional to the diameter of the jet causing the disturbance at corresponding Froude Number, when the Froude Number is based on the increase in dynamic pressure above that which initially causes spray. To provide further evidence that spray could be scaled from one diameter to another, it was decided to carry out tests over water with nozzles of varying diameter for a range of nozzle exhaust pressure and heights above the surface.

DESCRIPTION OF APPARATUS AND TEST PROCEDURE

A. Water Tank

A water tank 30 feet x 15 feet x 3 feet deep was constructed for the tests. It consisted of a wooden structure with a heavy plastic liner. The tank was constructed in the open air, and a filter was provided to maintain cleanliness of the water.

For tests with waves a sloping bed of sand and crushed rock covered with wire mesh was provided at one end of the tank to act as a wave absorber. Waves were generated by the vertical displacement of a 24.0" diameter cylinder at the opposite end. This wave generator was manually operated through a lever system. A sketch of this apparatus is shown in figure 2.

Figure 1 shows a general view of the tank.

B. Nozzles

To provide verification of the derived scaling expression tests were conducted with a series of three nozzles mounted over the test tank. The diameters of these nozzles were 2.50", 5.0" and 10.0" and the height above the water level could be adjusted between 0 and 40.0". Air to the nozzles was supplied through ducting from a Buffalo Forge blower, Type 35 MW, and this provided a maximum dynamic pressure of approximately 40.0 lb./sq.ft.

Initially tests were conducted over a solid board, the nozzle and board being instrumented as shown in figure 3, to give the relationship between the nozzle dynamic pressure (q_n) and the dynamic pressure parallel to the surface (q_s) at varying nozzle heights.

Tests were then carried out over the water at the following conditions, the resulting spray being recorded photographically.

D ins	2.5	5.0	10.0
z ins	2.5,5.0,7.5,10.0	5.0,10.0,15.0,20.0	10.0,20.0,30.0,40.0
q_n lb./sq.ft.	2.0 - 20.0	4.0 - 30.0	4.0 - 40.0

At each height the nozzle dynamic pressure at which spray was first detected was recorded.

C. X-100 Model

This model is basically a 0.15 scale model of the Curtiss-Wright X-100 research aircraft. However, the X-19 propellers were fitted to the model, since the disc loading as a function of R.P.M. of these propellers had been previously calibrated. These propellers are 1.56 ft. diameter compared with 1.50 for the original X-100 model propellers. The pertinent scaling factor for these tests is therefore 1/.156 = 6.41 (see section 6a). Figure 4 shows a sketch of the model and leading dimensions.

The propellers were driven by a single electric motor mounted internally in the model, power for which was supplied by a variable frequency motor-generator set.

The model was suspended over the center of the water tank from an overhead boom. Vertical movement of the boom gave a variation of model height above the water of from 0 to 60 inches.

The test procedure was to run the propellers to give the desired disc loading at a fixed height above the water. The resulting spray pattern was recorded by two movie cameras, one mounted parallel to the water surface and the other mounted perpendicular to the surface from an overhead platform. Still photographs were also taken.

At each height the propeller disc loading at which spray was first detected, $(T/A)_o$ was noted.

Tests were made with the X-100 model at the following heights above the water surface:

z inches	60	42	24	9.5
z/D	3.21	2.25	1.28	0.51

and at propeller disc loadings $(T/A)_M$ of

2.65, 3.65, 4.75, 6.0, 7.5, 9.0 lb./sq.ft.

All these tests were made at a propeller blade angle $\beta_{.671} = 16°$, and a few were repeated at 12° to check any possible effect on spray of change in load distribution along the blade.

D. X-19 Model

This is a 0.12 scale model of the Curtiss-Wright X-19 VTOL aircraft, which has four lifting propellers of 13 ft. diameter. The scale factor for these tests is therefore 1/.12 = 8.33 (see section 6a). A sketch of the model showing leading dimensions is given in figure 5.

The four propellers were driven by a single internally mounted electric motor. Power supply, model mounting, and photographic coverage of the tests were similar to that described for the X-100 model.

For basic tests of spray formation over calm water, the procedure was identical to that followed for the X-100, and the ranges of conditions covered were:

z inches	59	42	24	12
z/D	3.15	2.25	1.28	0.64

$(T/A)_M$ lb./sq.ft. 2.65, 3.65, 4.75, 6.0, 7.5, 11.0

Further spray tests were then carried out over 6 to 8 inch high waves, representing waves of approximately 5 feet height at full scale X-19 conditions. The test procedure adopted was similar to before, the propeller R.P.M. was adjusted to give the desired disc loading at a fixed height. The wave generator was then manually operated and when the conditions were stabilized, the resulting disturbance was recorded photographically.

Test conditions were identical to those over calm water with the exception that tests at 12.0 inches above the water were omitted to avoid the possibility of the lower part of the model being immersed by the wave peaks.

All the foregoing tests were made with a blade angle $\beta_{.671} = 16°$ and with equal disc loading on all four propellers. The model angle of attack was 0° with a few runs being made at ± 10°.

For all subsequent tests the forward propeller blade angles were maintained at 16° while the rear blade angles were reduced to 12°, to give a close representation of the full scale X-19 disc loadings in hover. Also the angle of attack was set at $2\frac{1}{2}$°.

Tests were then made to show the effect of propeller downwash and spray on objects floating below the model. A description of these objects and the test procedure is given below.

E. Model Life Rafts

0.12 scale models of a four-man life raft and a one-man life raft were constructed from information supplied in MIL-L-25691 (USAF) and MIL-L-8664A (Aer.). Scale models of men were also constructed. The weights of the rafts with the model men installed were approximately correct for dynamic similarity, but no check was made of the moments of inertia, although this should not be seriously in error.

	Full Scale Weight	Scaled Weight	Actual Model Weight
Four-man life raft, including men.	850 lb.	1.47 lb.	1.70 lb.
One-man life raft, including man.	214 lb.	0.37 lb.	0.35 lb.

The procedure used in tests with the rafts was to pull the raft through the disturbed water with a length of thin string. There was some tendency for the string to affect the stability of the rafts and this was minimized as far as possible.

RESULTS AND DISCUSSION

A. Theoretical Results

In order to obtain scaled parameters of the motion of water from model tests, it is necessary to operate at full scale Froude Number, which is proportional to V^2/L where V is a velocity and L is a characteristic length. Work on ship and flying boat hulls have shown that, providing the Froude scaling is followed, the spray formation produced by a model is geometrically similar to that produced by the full scale article.

In the case of a propeller driven VTOL airplane hovering over water the velocity and length required in the Froude Number would be the resultant slipstream velocity parallel to the water surface (V_s) and propeller diameter (D).

Therefore Froude Number is proportional to V_s^2/D, or q_s/D

In some previous spray tests (references 1 and 2) and from observations of wind over the open ocean (reference 3) it was found that spray will not form below a certain value of the surface dynamic pressure (q_{s_o}) and this figure lies between 1.5 and 2.5 lb./sq.ft.

Since q_{s_o} will be independent of scale, the spray formation will depend on the increase of surface dynamic pressure above q_{s_o}.

It would, therefore, seem that in order to obtain geometrically similar spray patterns from model and full scale aircraft

$$\left(\frac{q_s - q_{so}}{D}\right) \text{full scale} = \left(\frac{q_s - q_{so}}{D}\right) \text{model scale} \tag{1}$$

The dynamic pressure parallel to the water will be a function of the dynamic pressure perpendicular to the surface q, which will in turn be a function of the propeller disc loading depending on the height of the propeller above the surface.

i.e.
$$q_s = \frac{q_s}{(T/A)} \cdot (T/A) \tag{2}$$

and
$$q_{so} = \frac{q_s}{(T/A)} \cdot (T/A)_o \tag{3}$$

therefore
$$\frac{q_s - q_{so}}{D} = \frac{q_s}{(T/A)} \cdot \left[\frac{T/A - (T/A)_o}{D}\right] \tag{4}$$

and
$$\frac{q_s}{(T/A)} \left[\frac{(T/A)-(T/A)_o}{D}\right] \text{full scale} = \frac{q_s}{(T/A)} \left[\frac{(T/A)-(T/A)_o}{D}\right] \text{model scale} \tag{5}$$

let $D_F/D_M = S$ (The model scale factor)

then, since $\frac{q_s}{(T/A)}$ and $(T/A)_o$ are independent of scale, it follows that at constant z/D, for geometrically similar spray,

$$(T/A)_F = S\ (T/A)_M + (1-S)\ (T/A)_o \tag{6}$$

References 1 and 2 give results of some small scale spray tests and these have been correlated using the above expression. Reference 1 shows results from a 4.0 inch diameter nozzle and a 16.0 inch diameter ducted fan and are repeated in figure 6a. There is considerable scatter in the results, and the lines drawn through the points do not exactly correspond with those shown in reference 1. Although stating that the spray height remains zero up to a q_s of approximately 2 lb./sq.ft., the curves drawn in that report pass through the origin. They have therefore been redrawn showing $h = 0$ at $q_s = 2.0$.

It is pointed out in reference 1 that the 4.0" diameter results do not scale up to the 16.0" diameter values at similar Froude Number (q_s/D). However when equation 1 is used to compare the results very good agreement between the 4.0 inch nozzle and the 16.0 inch ducted fan is apparent, as shown in figure 6b.

Reference 2 gives some spray results on a two dimensional basis, and the parameter used in presenting the results from three different width nozzles is spray angle, rather than the spray height parameter used in reference 1. These results are shown in figure 7a and again, when a comparison of the results is made using equation 1 as a basis, good agreement is shown in figure 7b.

The limited correlation made above is encouraging, but to provide a further experimental check, the series of tests with varying diameter nozzles was initiated and the results of these tests is discussed below.

B. Experimental Results

1. Jet Impingement Nozzles

The tests with the three nozzles were initially carried out over a solid board and the variation between the maximum dynamic pressure parallel to the surface and the nozzle dynamic pressure was measured. Figure 8a shows the results of these tests and it is shown that the ratio of q_s/q_n is independent of nozzle diameter. The results of further tests to determine the nozzle pressure at which spray was first detected are shown in figure 8b, and again it is shown that q_{n_o} is virtually independent of nozzle size. Combination of figures 8a and 8b give a value of q_{s_o} of between 1.70 and 1.90 lb./sq.ft. which confirms the results given in references 1, 2 and 3.

Since it is shown that q_{s_o} and q_s/q_n vary only with z/D, the scaling expression $\frac{q_s - q_{s_o}}{D}$ = constant, can be rewritten

$\frac{q_n - q_{n_o}}{D}$ = constant at a fixed value of z/D.

The height of the spray produced in the tests of the nozzles over water was measured from still photographs. This is defined as the maximum height at which any spray is observed. The spray pattern was not completely static and therefore some scatter of the results was to be expected.

The ratio of spray height to nozzle diameter is plotted in figure 9 against the ratio $\frac{q_n - q_{n_o}}{D}$ at constant z/D. It was felt that the results from the three nozzles compared sufficiently well to justify the use of the derived scaling expression.

It was noticed that although the spray height scaled reasonably well, the appearance of the spray changed with size of nozzle. The 10.0 inch diameter nozzle produced a fine mist-like spray, whereas the spray had a coarse appearance at the same value of z/D with the 2.5 inch diameter nozzle. This phenomena had been noted in reference 1 and is attributed to the effects of surface tension which prevents the break up of the water into scale size droplets. However, both these tests and towing tank experience indicate that although the appearance of the spray is different, model tests will give the correct geometric pattern.

2. X-100 Tests

The maximum heights at which spray was observed in the X-100 model tests are shown plotted against model disc loading in figure 10. These results may be used to predict the spray height for a full scale aircraft by the use of equation 6, and for the particular case of the full scale X-100 aircraft at a disc loading of 23 lb./sq.ft. the spray height derived from the model tests is shown in figure 11.

During the flight test program on the X-100, one flight was made over a pond of water and the spray pattern is shown in figure 12 and the spray height is compared with the predicted results in figure 11. The agreement is close and provides further evidence that model tests may be used in predicting full scale spray. Here again, it should be noted that the full scale spray has a more misty appearance than that obtained from model tests.

The general appearance of the spray in the model tests is shown in figure 13, where it can be seen that the majority of the spray is swept forwards and reaches a maximum height ahead of the model.

The initial propeller blade angle for the tests was 16° and to check whether a change in total pressure distribution across the slipstream caused any difference in the spray produced, a few tests were run at each height at a blade angle of 12°. No significant change in spray height was recorded.

3. X-19 Tests

The maximum heights at which spray was observed with the X-19 model over calm water are shown in figures 14 a and b. When compared with the results obtained with the X-100 model, it is shown that as the height of the model is decreased, the X-19 produced a lower spray height than was apparent with the X-100 model at the same disc loading. This may be due to the interaction of the front and rear propellers on the X-19 producing a plume of spray at right angles to the fuselage. The existence of this could decrease the amount of spray thrown forward and aft by the two forward (or aft) propellers alone, as is the case in the X-100 configuration. The results of tests over waves of between 6 inches and 8 inches in height are shown in figure 14c and here the spray height is slightly higher than the calm water results.

All these tests were made with equal disc loading on all four propellers, whereas on the full scale X-19 the forward propeller disc loading is approximately 50% higher than that for the rear propellers. Therefore, at each height one test was carried out at approximately scaled X-19 conditions. However, when these results, based on the mean disc loading, are compared with the previous tests no significant difference was apparent. It is therefore reasonable to assume that the model results at equal disc loading can be scaled up to predict the full scale X-19 spray characteristics, and this is shown in figure 15 for a mean full scale disc loading of 25.5 lb./sq.ft.

The waves generated in the test tank represented, at full scale X-19 conditions, a wave height from trough to peak of about 5.0 ft., and a wave length of about 50.0 ft. This corresponds to a sea state of code 3 to 4 (moderate to rough) or a swell condition of code 1 (low swell, short or average).

A selection of photographs showing the spray produced by the X-19 model is shown in figures 16 and 17.

The spray produced by both the X-100 and X-19 models form a diffuse pattern, the top of the spray cloud consisting of fairly fine spray. Since it would be difficult to distinguish between spray that may prove objectionable to aircraft operation and the fine spray that would be of little embarassment, the spray heights shown in this report are heights at which any spray was observed. A further point to note is that the full scale spray may have a more misty appearance that that produced by model tests, as discussed earlier.

The spray heights were taken from the projection of the colored still photographs of the tests. Caution should be exercised in relating the plotted results with the published photographs, since some of the fine spray seen in the slide projection may not be visible in the printed photograph.

An edited motion picture record of the tests is available and this will illustrate more graphically the general appearance of spray than a written presentation.

4. Tests with Life Rafts, etc.

In order to assess the effects of downwash on objects floating beneath an X-19 aircraft in an air-sea rescue role, 0.12 scale model life rafts and men were floated beneath the model in calm conditions and with waves.

Here again the motion picture record will be more informative than a written description.

Tests were carried out at heights representing 40 ft., 30 ft. and 16.5 ft. full scale, and in all these conditions, the rafts were subjected to considerable buffeting. However, the four-man life raft remained erect and although it was flooded at the lower model heights rescue could probably still be effected at low heights above the raft.

The one man life raft appeared much less stable, and with the model at an z/D of 2.25 (30 ft. full scale) the raft was in danger of capsizing. However, it should be noted here that no sea anchor was represented in the tests. Also, the rafts were pulled through the disturbance caused by the model with a length of string which may have affected the stability of the raft. This effect was minimized by releasing the string when the raft was directly beneath the model.

It does appear, therefore, that rescue from a one-man life raft should be effected from a height of greater than 30 feet.

Tests were also carried out with a model of a man in survival gear floating in the water beneath the X-19 model. The "man" remained floating on the surface in these tests although he would be subjected to severe buffeting.

5. X-19 Tests with Tilt Floats

In order to demonstrate the water-basing capabilities of the X-19, the model was fitted with "tilt floats" as shown in figure 5. Tests were then run over calm water and waves, with the model being lowered from an z/D of 3.10 (40 ft. full scale X-19) to water level. The floats appeared to have no effect on the spray produced and the resulting disturbance caused by this simulated landing is shown in the motion picture record, which is self explanatory. Similar tests with "flotation bags" fitted to the rear nacelles also showed no effect on spray. It should be noted that the model was rigidly fixed and in any case was not dynamically scaled as regards weight, so that these tests only showed the effect of the model on the water and not the effect of water disturbance on model stability.

CONCLUSIONS

It has been assumed that VTOL model tests over water will give correct full scale spray patterns providing disc loading is scaled to give the correct Froude Number based on the increase in surface dynamic pressure above that which initially causes spray.

Correlation of spray tests carried out by other investigators, and of tests reported herein, of spray produced with a range of nozzles of varying diameter is presented to justify the above thesis.

Tests with a twin propeller X-100 and a four propeller X-19 model show that interaction between adjacent downwash at the water surface causes a plume of spray to be produced between the propellers. The spray rises to a considerable height, but much of the upper part of the spray cloud consists of a very fine spray.

Excellent agreement is shown between full scale results from X-100 tests over water at a disc loading of 23 lb./sq.ft. and height of 21 ft. and the spray height predicted from model tests for this aircraft.

The model test results indicated that a hovering aircraft using disc loadings above about 35 lb./sq.ft. will generate intense spray fields. Below disc loadings of 35 lb./sq.ft. only moderate spray is formed which should make possible practical over water operation.

Test results indicate that the actual X-19 airplane will not produce objectionable spray characteristics even when hovering at its most adverse loading condition and maximum overload gross weight.

It appears that there will be little if any water ingested into the engine air intake nor any impairment of crew vision even at very low heights above the water. At altitudes above about 40 feet the X-19 will not produce any spray for wave heights of 5 feet or less. Furthermore, at altitudes less than about 40 feet, operation over 5 foot waves would cause only a small increase in the spray height experienced over calm water, and will not result in any marked deterioration of operational capability.

The X-19 configuration would seem to be ideally suited to the tilt float concept (refs. 4 and 5). With a cylindrical float attached to each nacelle, the aircraft would have the ability to alight on the water surface from the hover attitude, the floats providing a very stable platform even in rough seas. This would eliminate the hazards and limitations of rescue from a hovering aircraft, for example, the danger of swamping or capsizing life rafts by hovering directly above them would be avoided, and it would be possible to take aboard unconscious or injured personnel.

The tilt float installation tested on the X-19 showed no detrimental effects on the spray pattern and it is therefore concluded that an X-19 fitted with tilt floats would result in a water based VTOL airplane free from any operating limitations due to the formation of spray.

Tests with various life rafts floating beneath the X-19 model showed that rescue is most desirably effected from altitudes of about 40 feet or higher. Rescue could probably be effected, however, at lower altitudes - down to about 16 feet for a four-man life raft and about 30 feet for a one-man life raft.

The tests involving floating objects below the X-19 model were of a limited nature, and it is felt that this is an area where further research would be beneficial. It is suggested that further tests could be carried out over a wide range of disc loadings with models of life rafts that are correctly scaled for weight, inertia and C.G., and with the use of sea anchors.

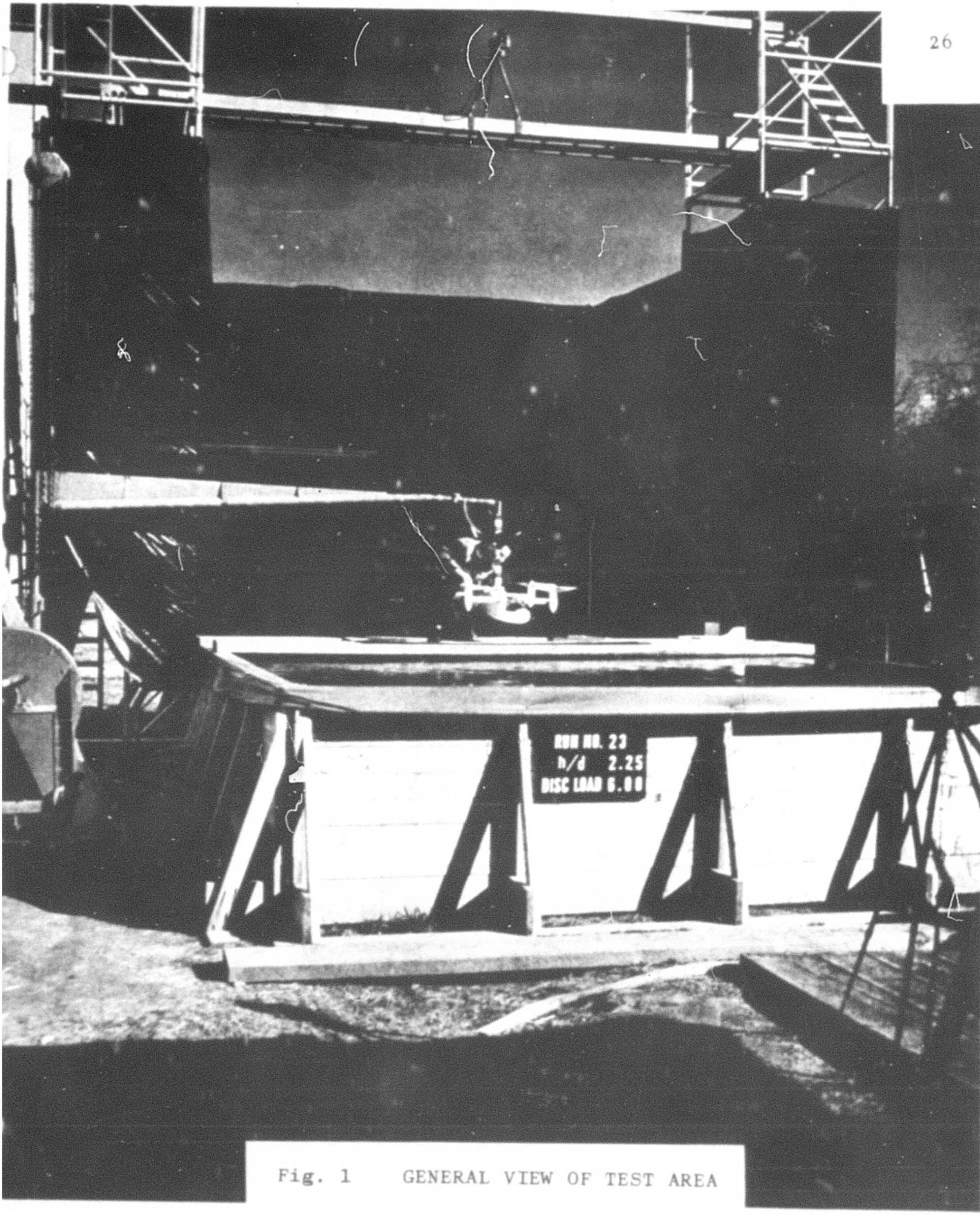


Fig. 1 GENERAL VIEW OF TEST AREA

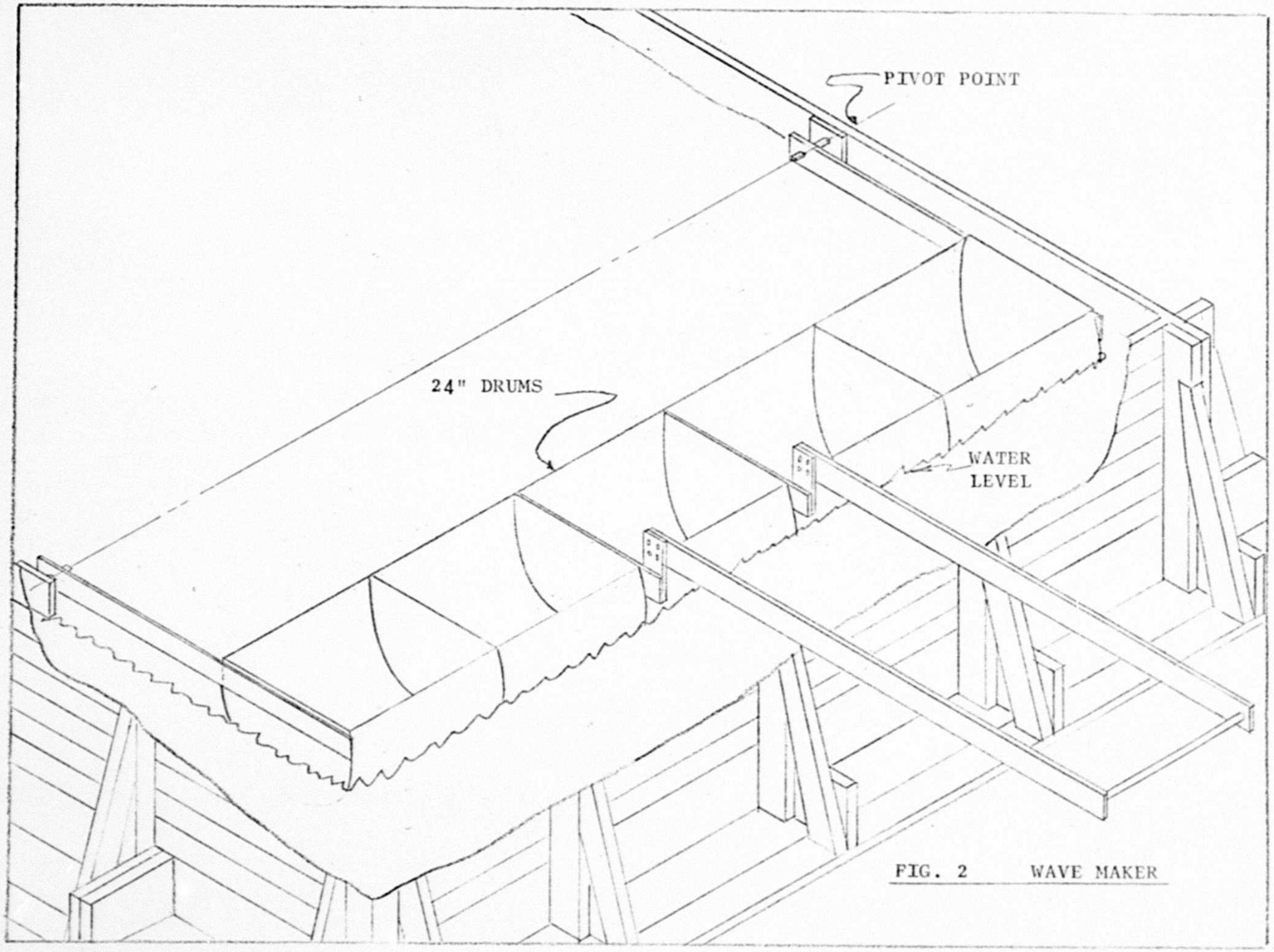


FIG. 2 WAVE MAKER

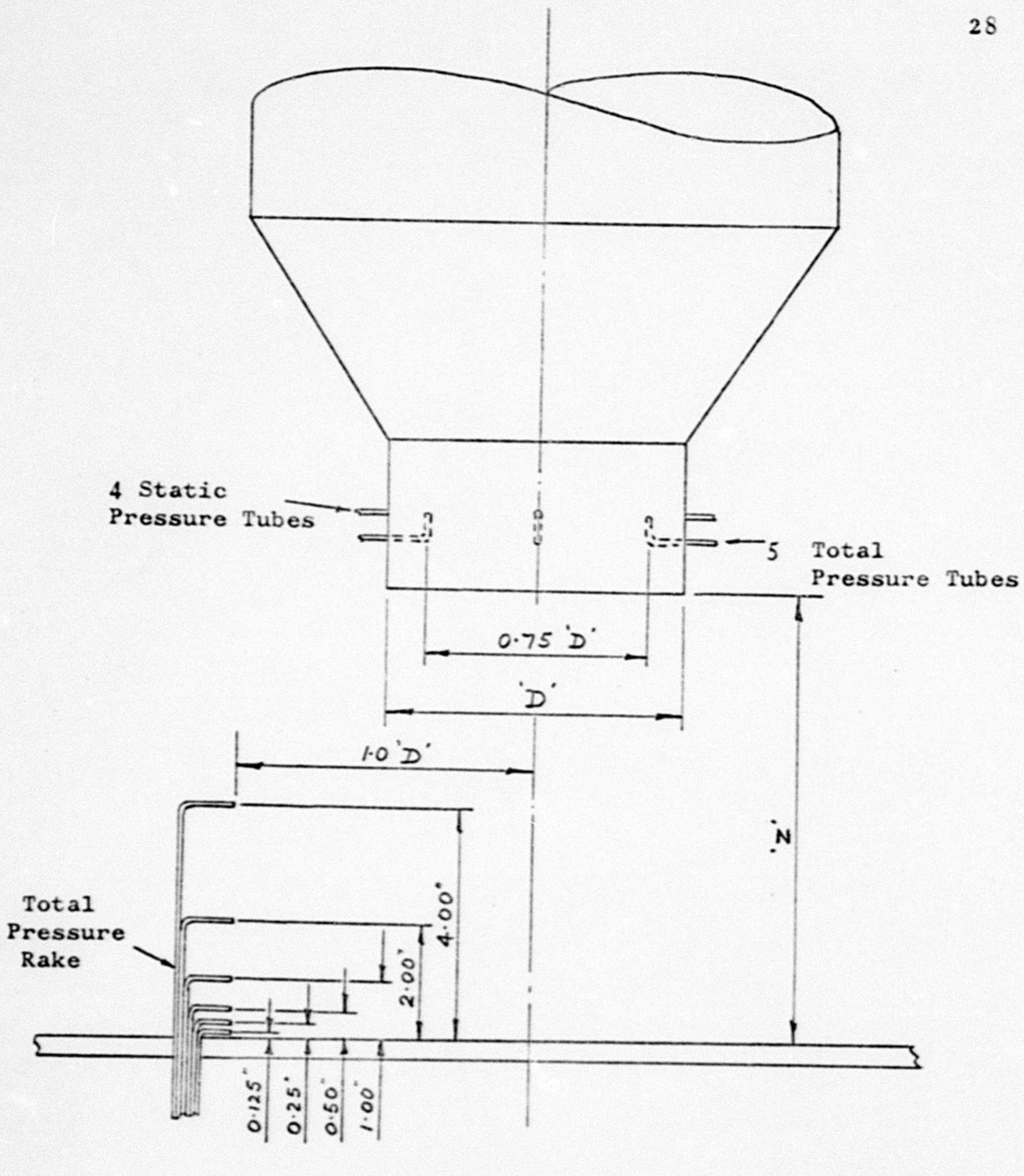


FIG. 3 NOZZLE INSTRUMENTATION

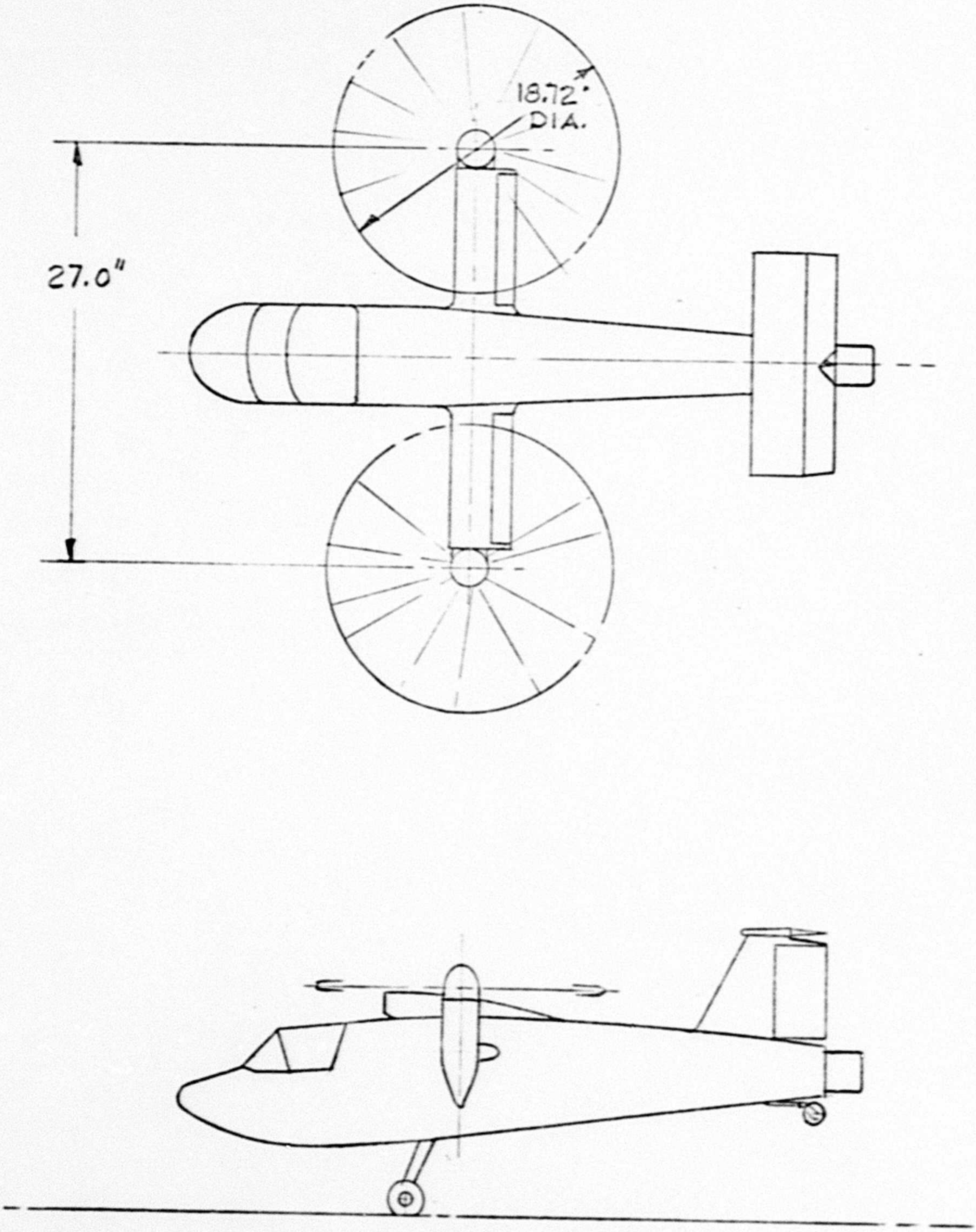


FIG. 4 0.15 SCALE X-100 MODEL

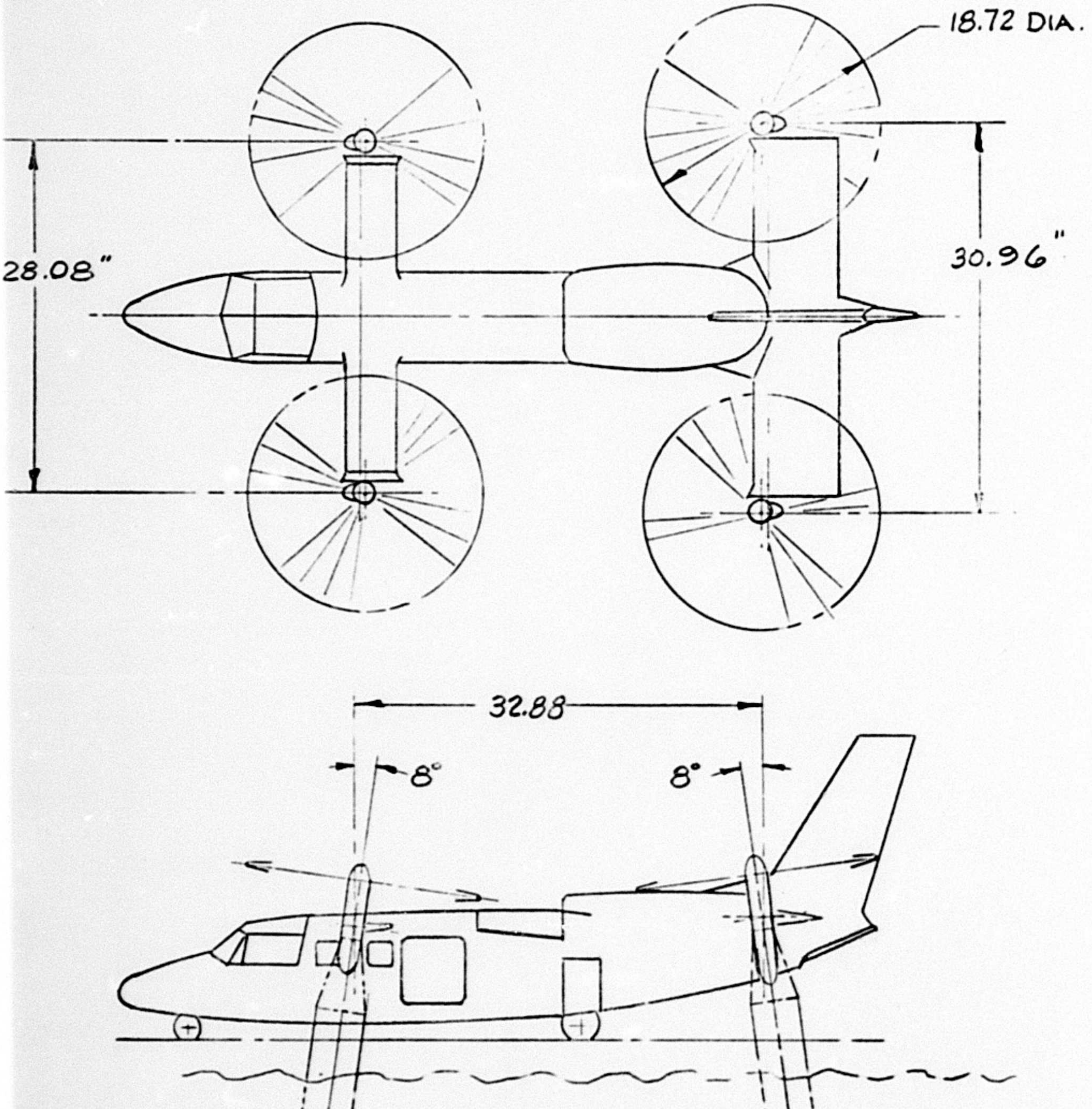


FIG. 5 0.12 SCALE X-19 MODEL

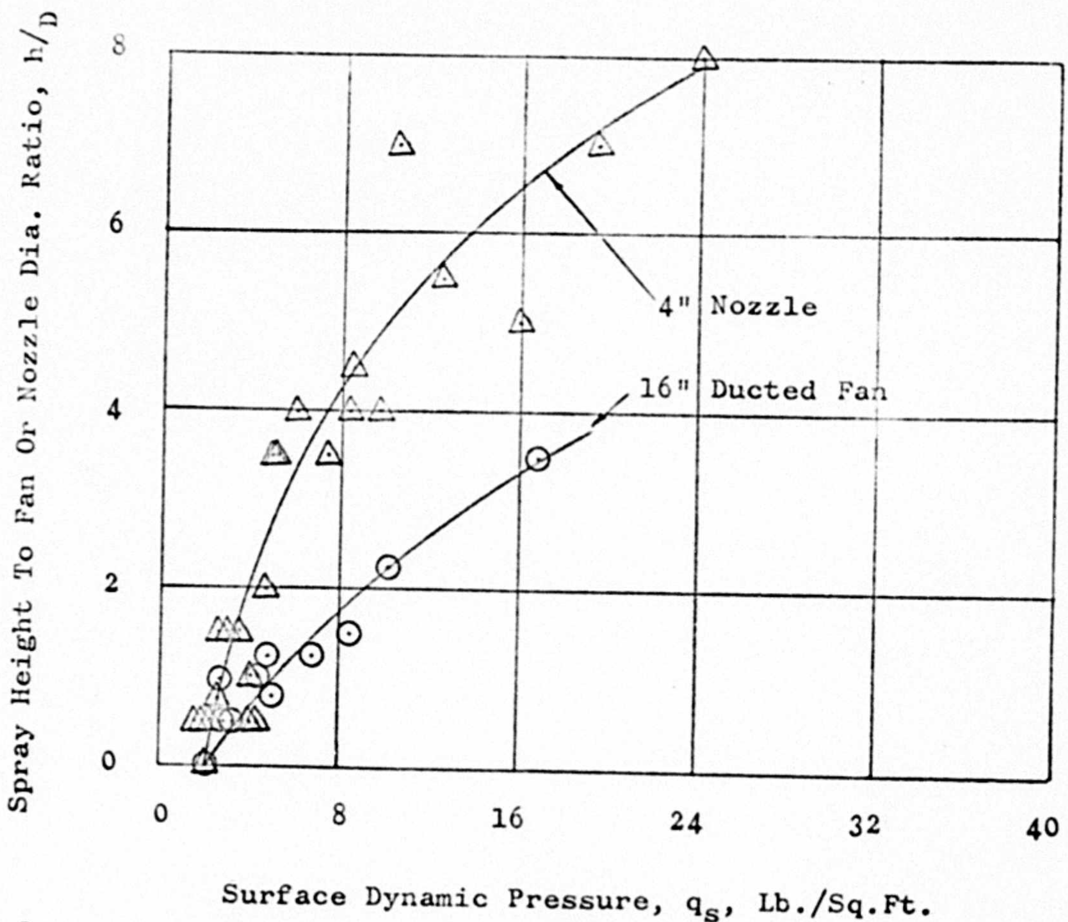


FIG. 6a DATA FROM NASA TN D-56

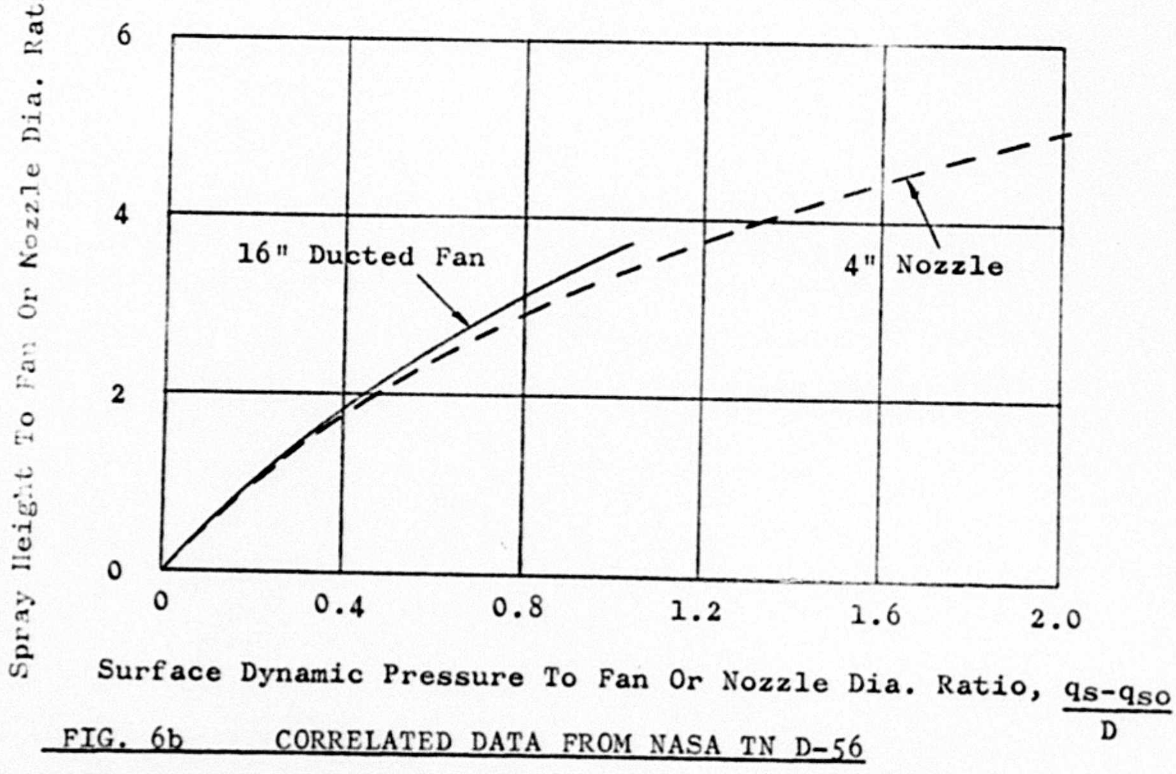


FIG. 6b CORRELATED DATA FROM NASA TN D-56

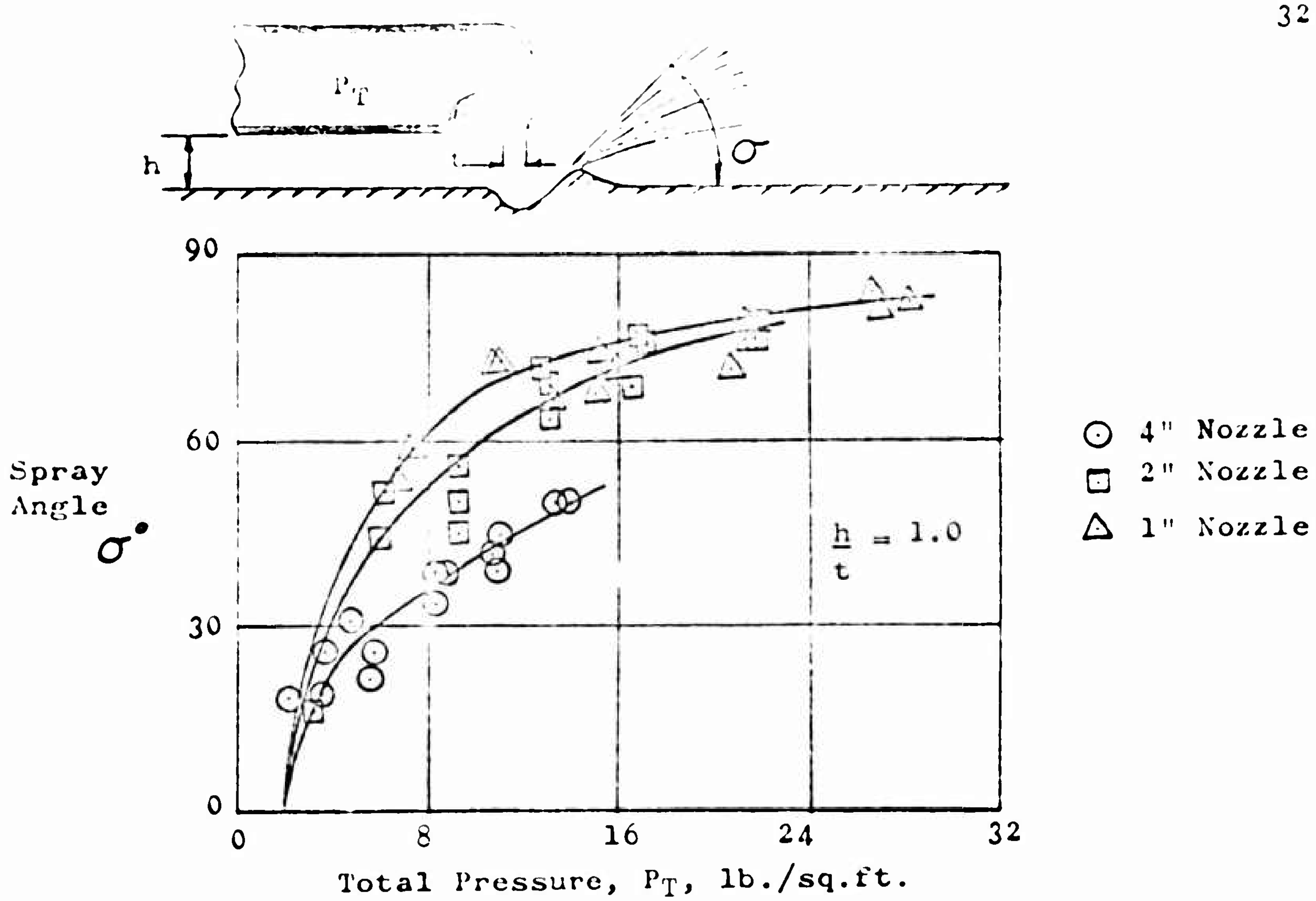


FIG. 7.a) DATA FROM IAS PAPER NO. 60-14

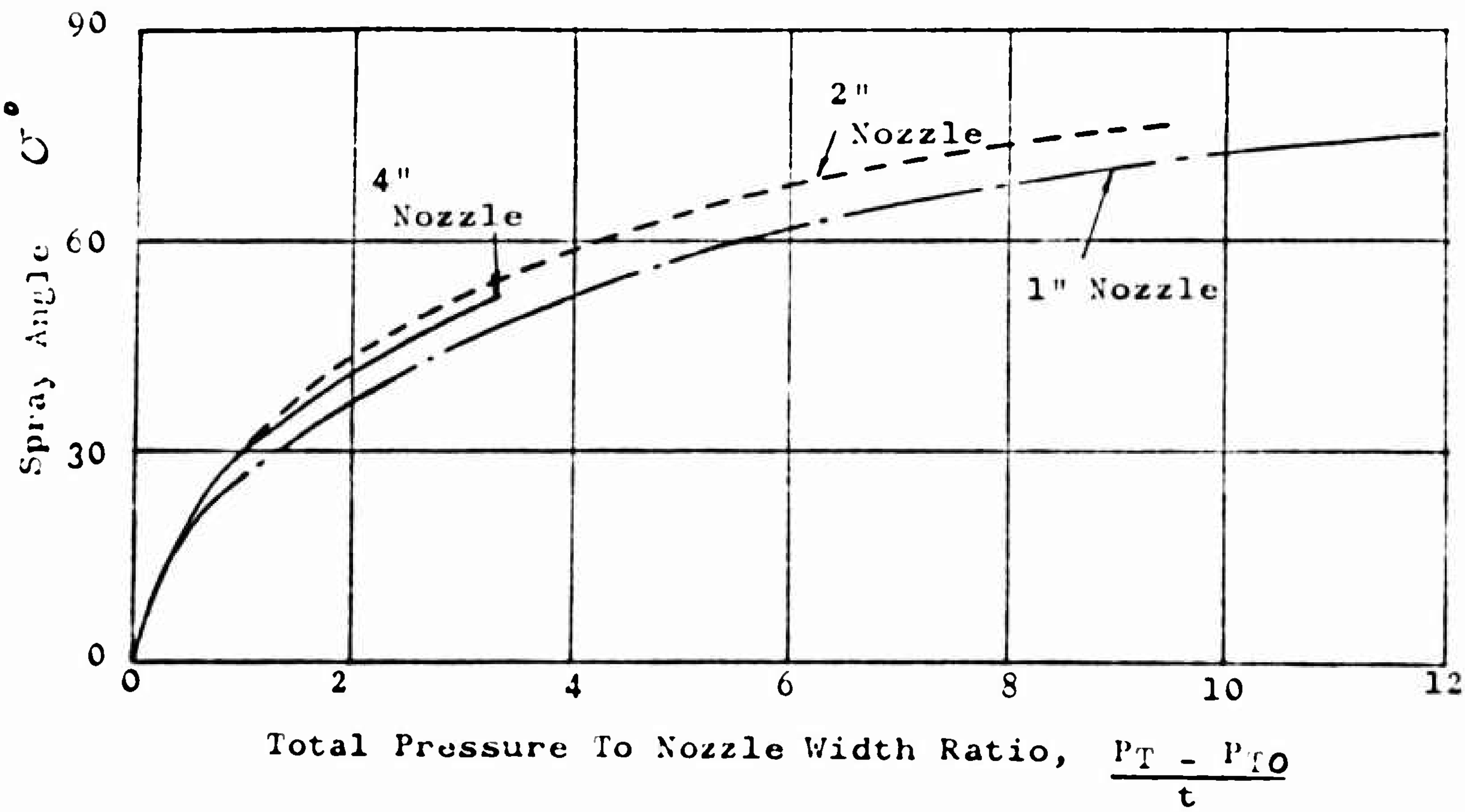


FIG. 7.b) CORRELATED DATA FROM IAS PAPER NO. 60-14

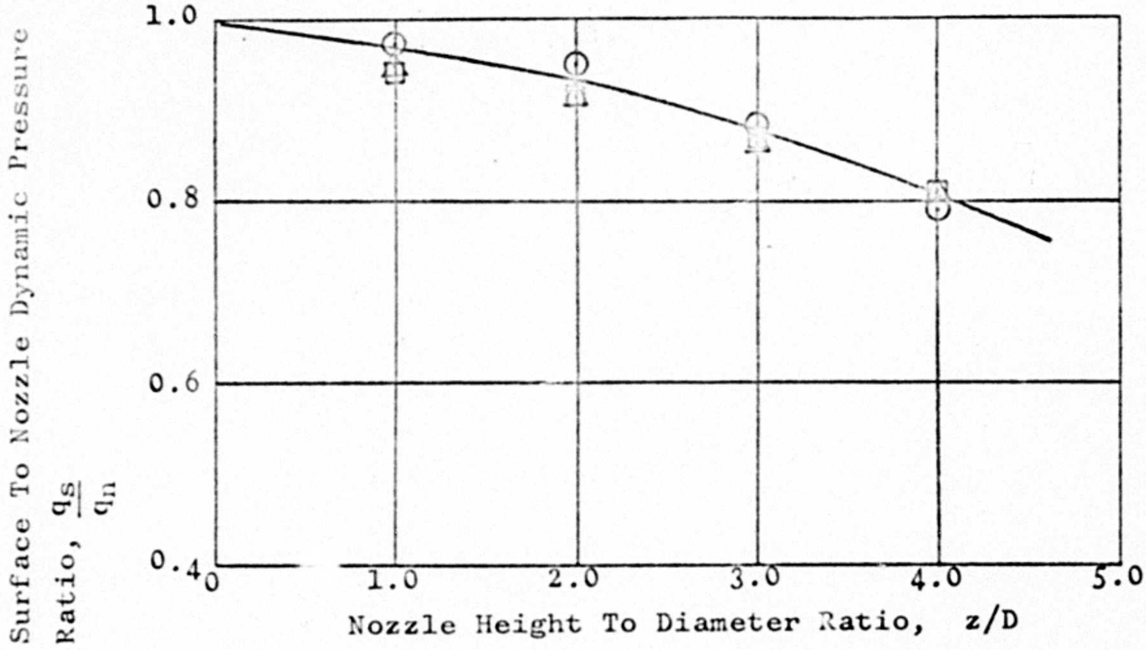


FIG. 8. a) RATIO OF NOZZLE DYNAMIC PRESSURE TO SURFACE DYNAMIC PRESSURE

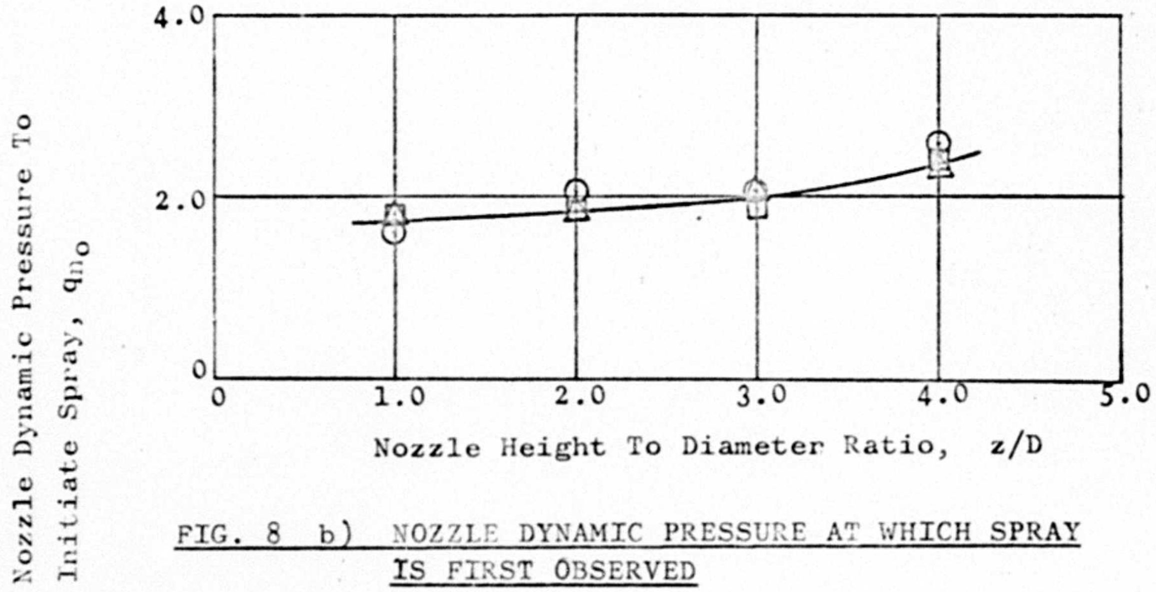


FIG. 8 b) NOZZLE DYNAMIC PRESSURE AT WHICH SPRAY IS FIRST OBSERVED

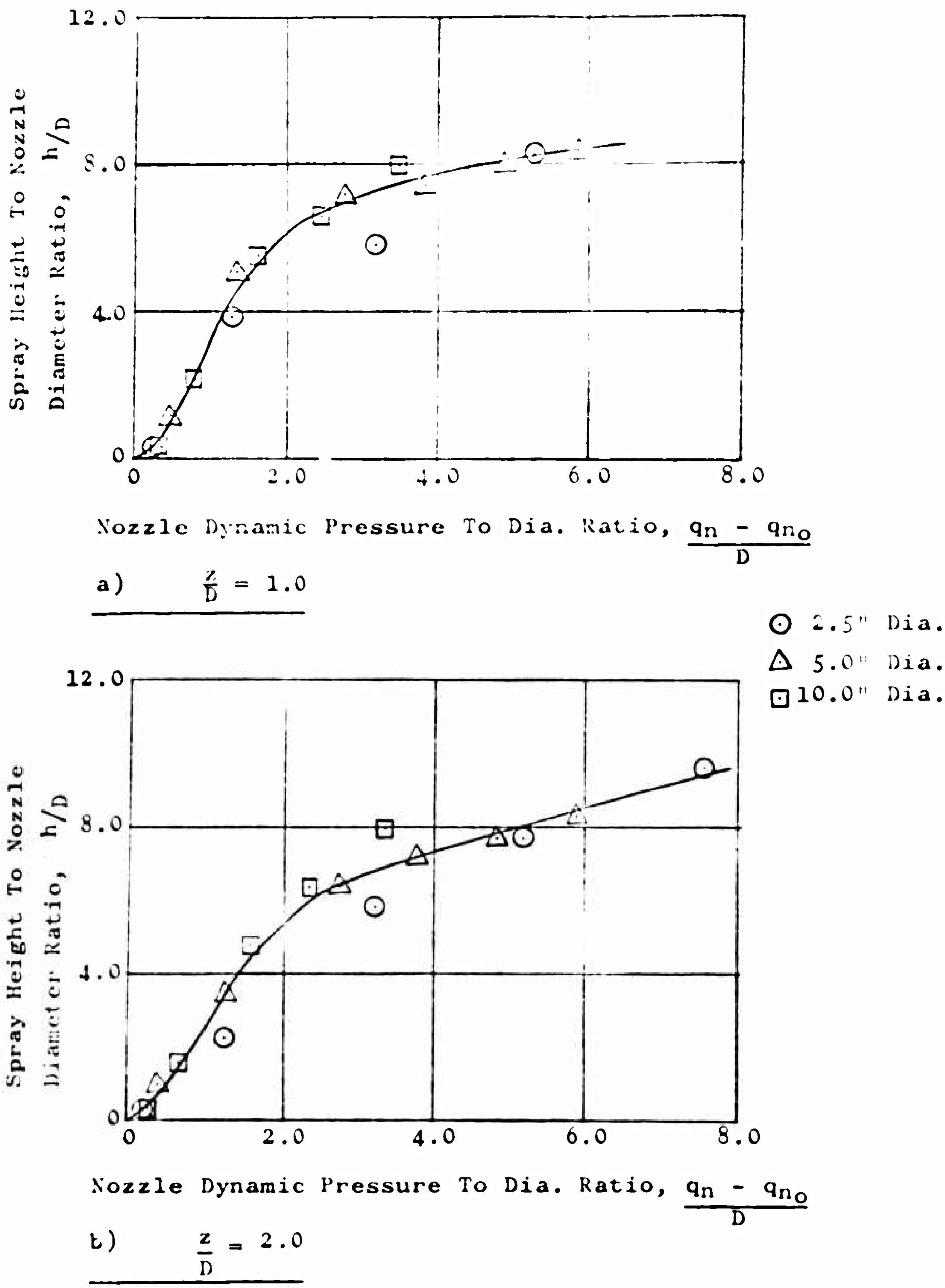
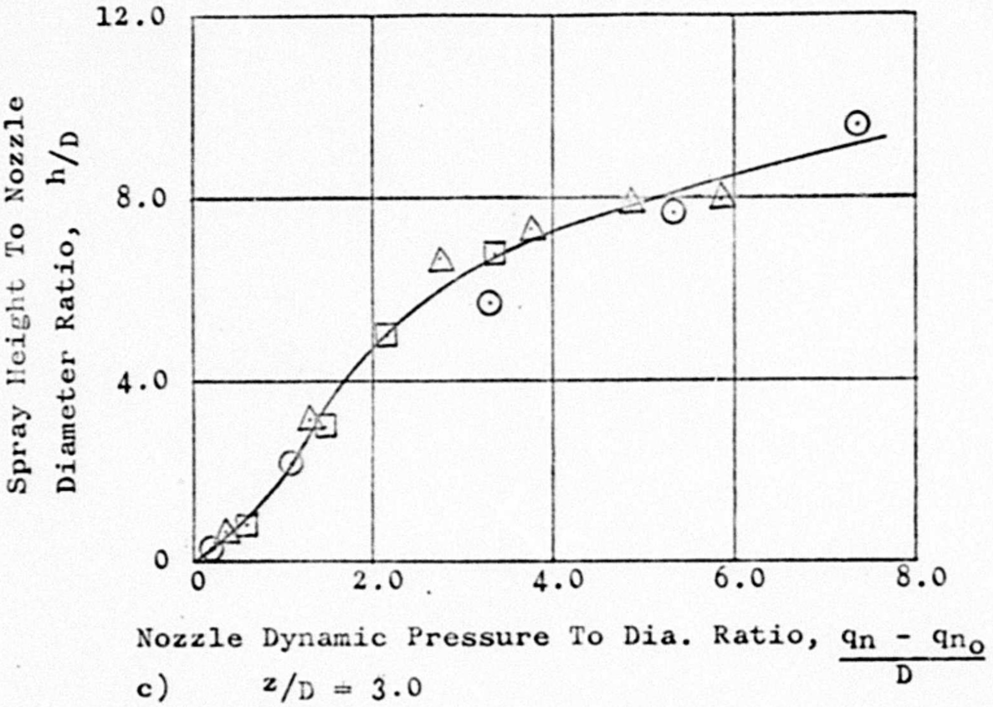
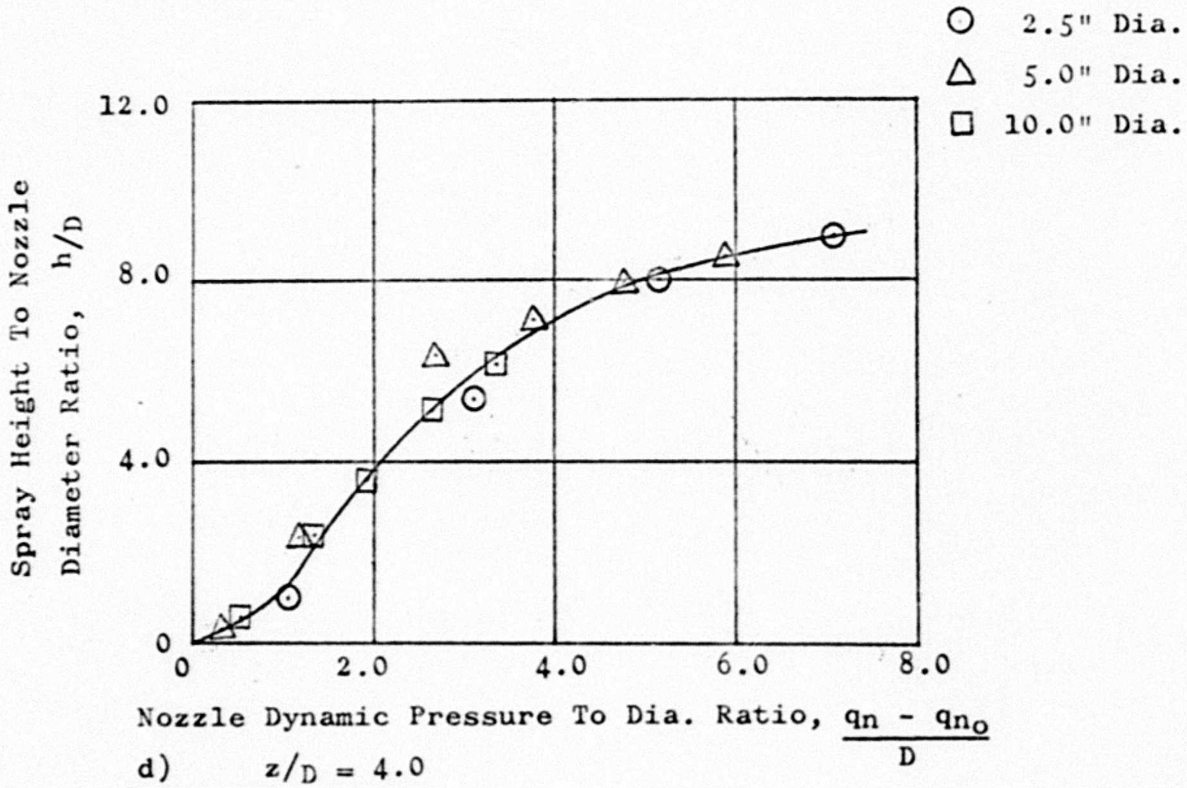


FIG. 9 SPRAY HEIGHTS AT VARIOUS NOZZLE PRESSURES

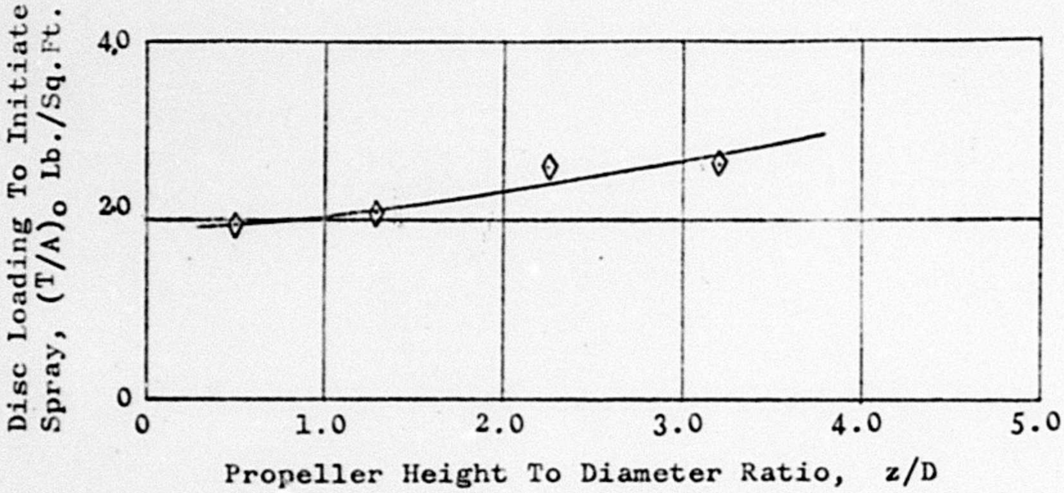


c) $z/D = 3.0$

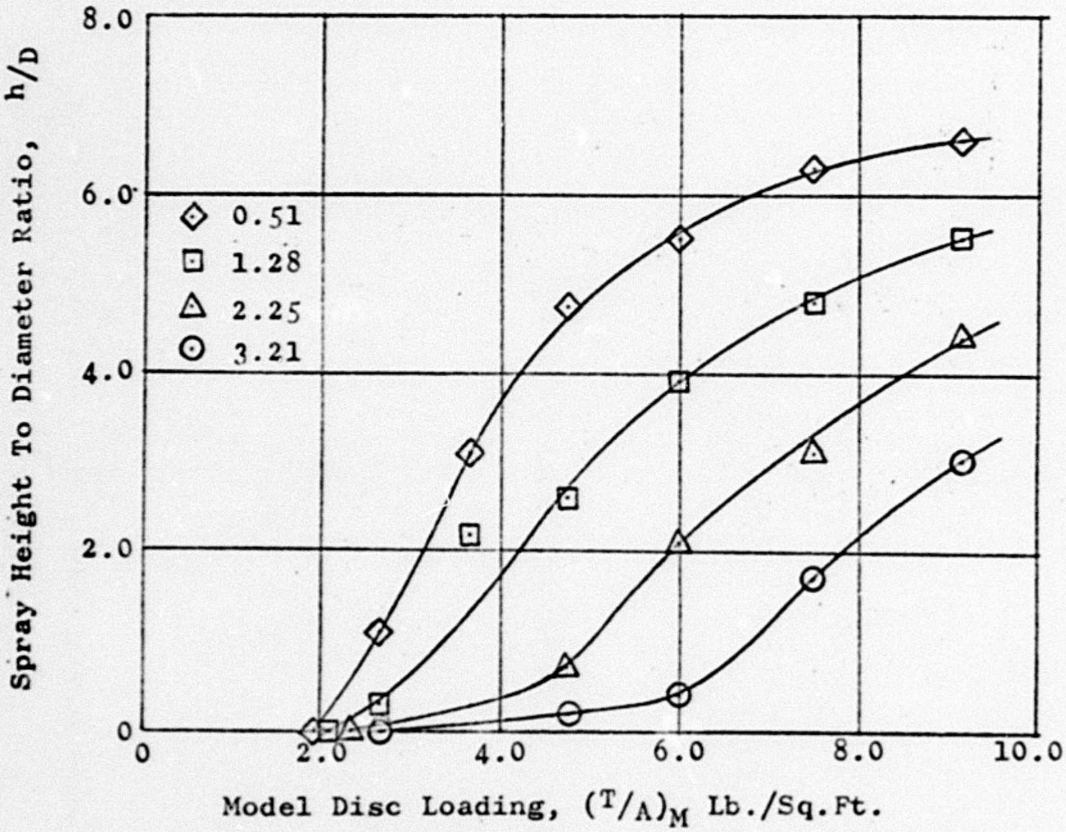


d) $z/D = 4.0$

FIG. 9 CONCLUDED



a) Disc Loading At Which Spray Was First Detected



b) Height At Which Spray Was Observed At Various Disc Loadings

FIG. 10 X-100 MODEL TEST RESULTS

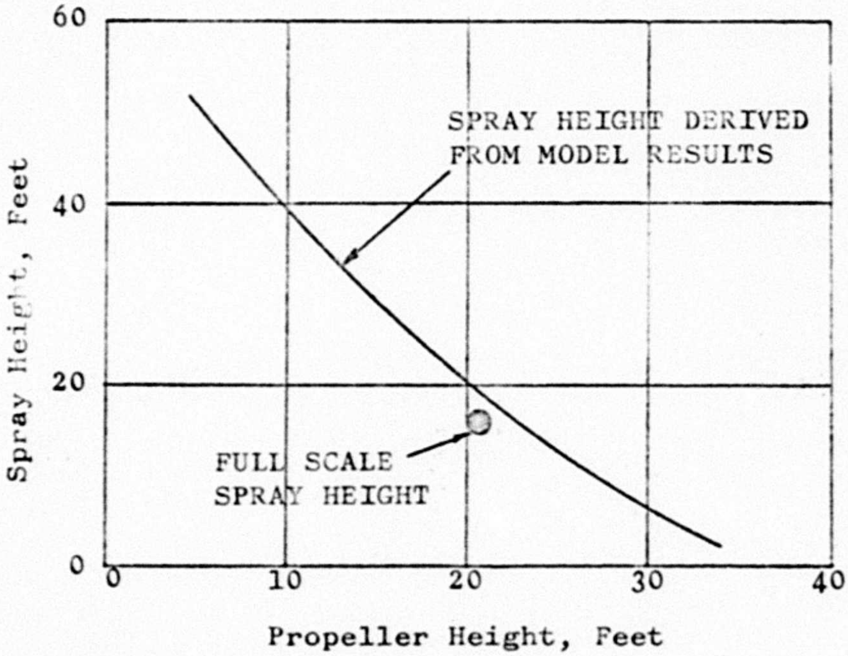
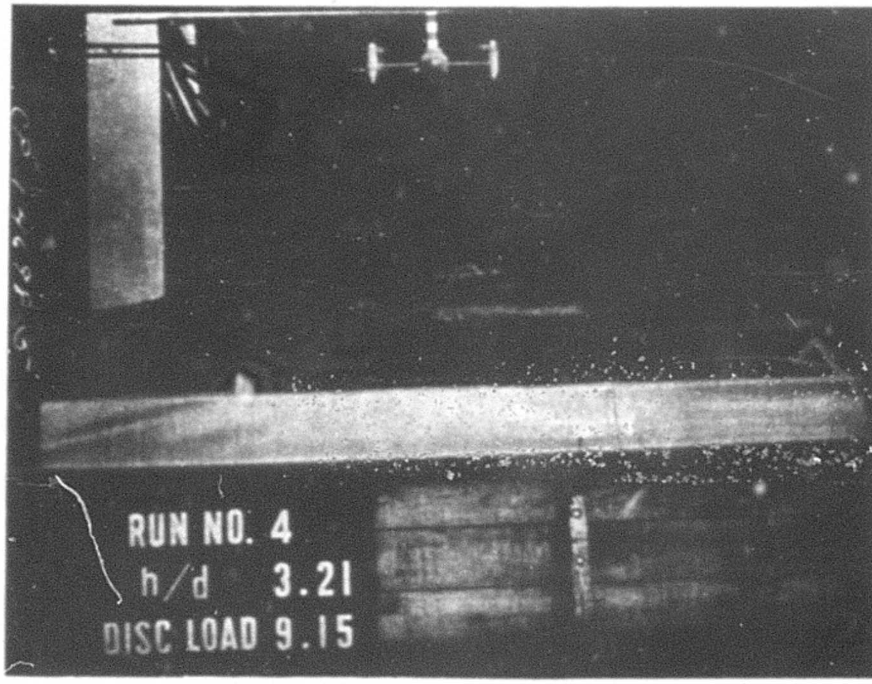


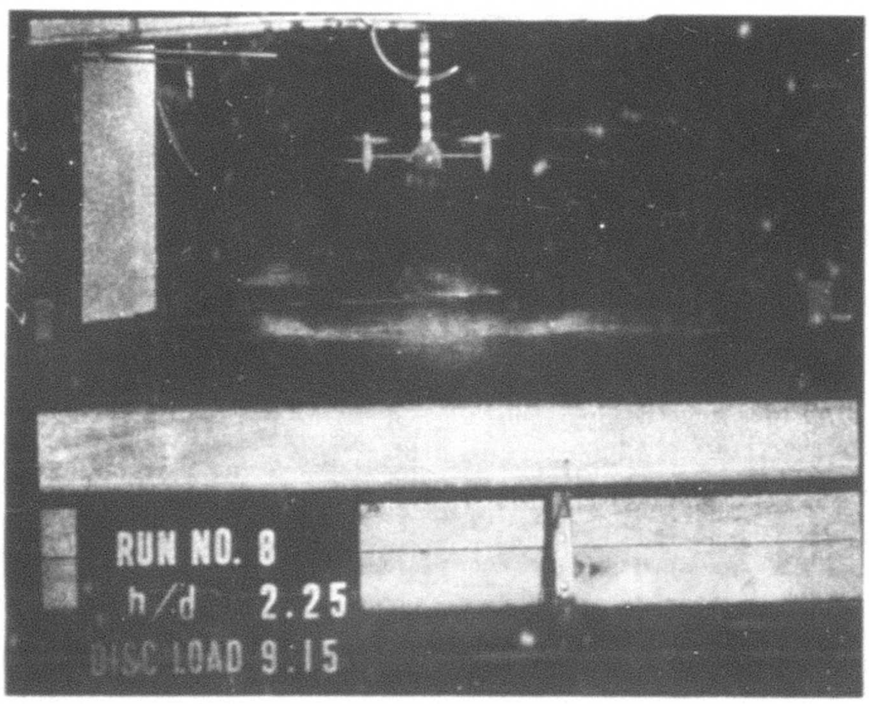
FIG. 11 SPRAY HEIGHT FOR FULL SCALE X-100
DISC LOADING 23 LB./SQ.FT

Height, z = 21 Ft. Approx.
Disc Loading, T/A = 23 Lb./Sq.Ft. Approx.

FIG. 12 X-100 AIRCRAFT OVER WATER

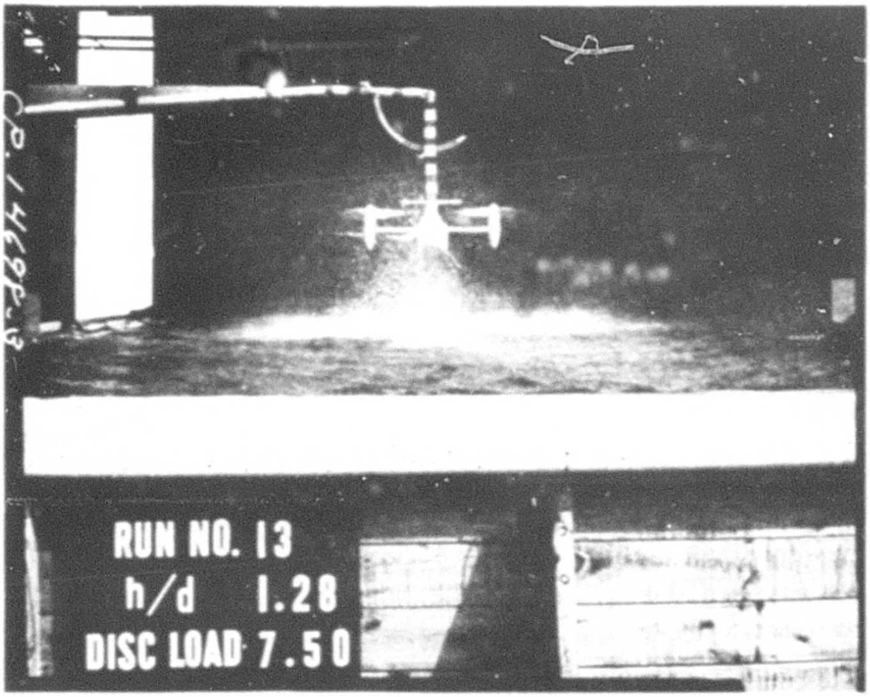


a) Full Scale Height 32.1 Ft.
Full Scale Disc Loading 45 Lb./Sq.Ft.

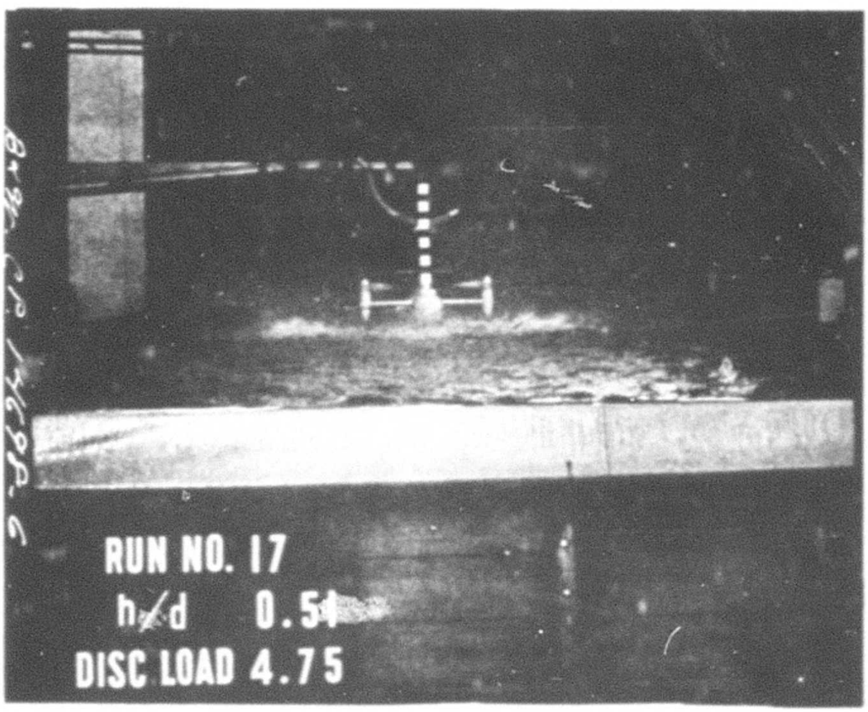


b) Full Scale Height 22.5 Ft.
Full Scale Disc Loading 46 Lb./Sq.Ft.

FIG. 13 X-100 MODEL TESTS

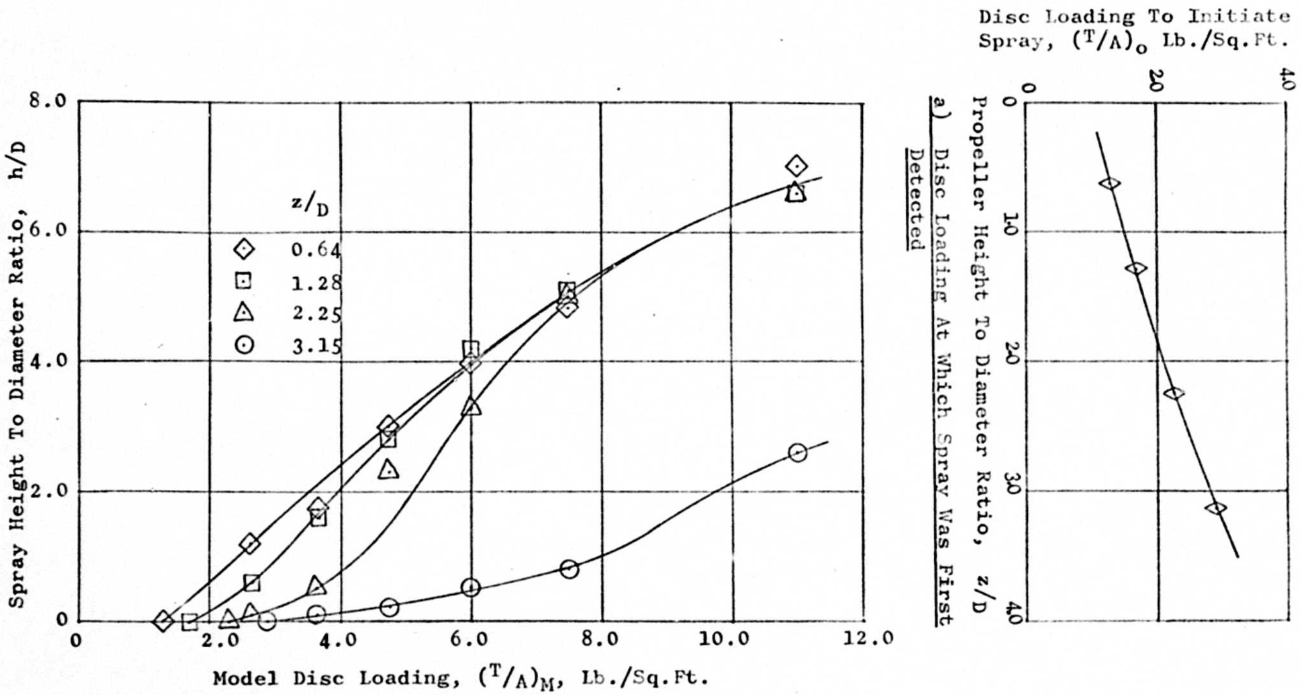


c) Full Scale Height 12.8 Ft.
Full Scale Disc Loading 37 Lb./Sq.Ft.



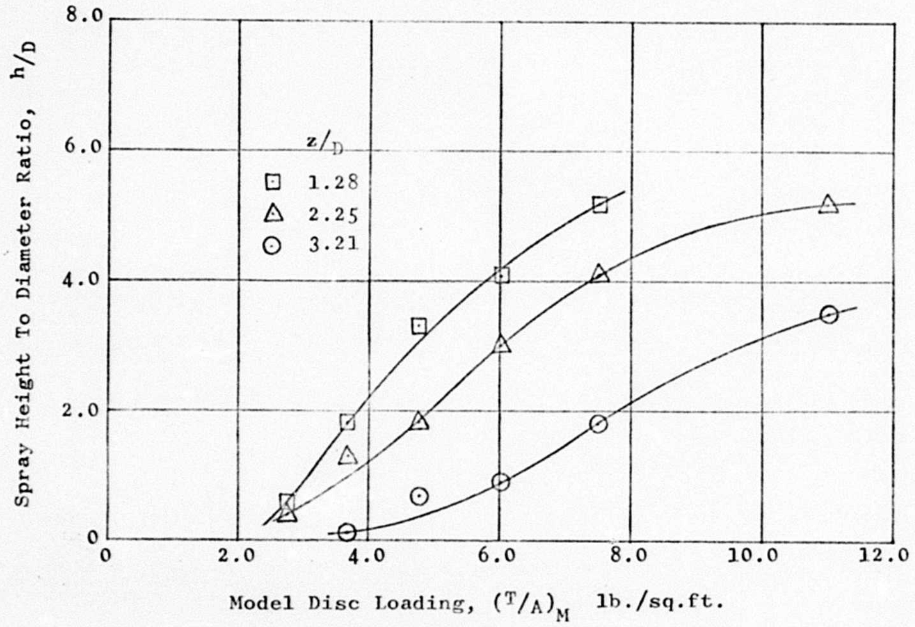
d) Full Scale Height 5.1 Ft.
Full Scale Disc Loading 20 Lb./Sq.Ft.

FIG. 13 CONCLUDED



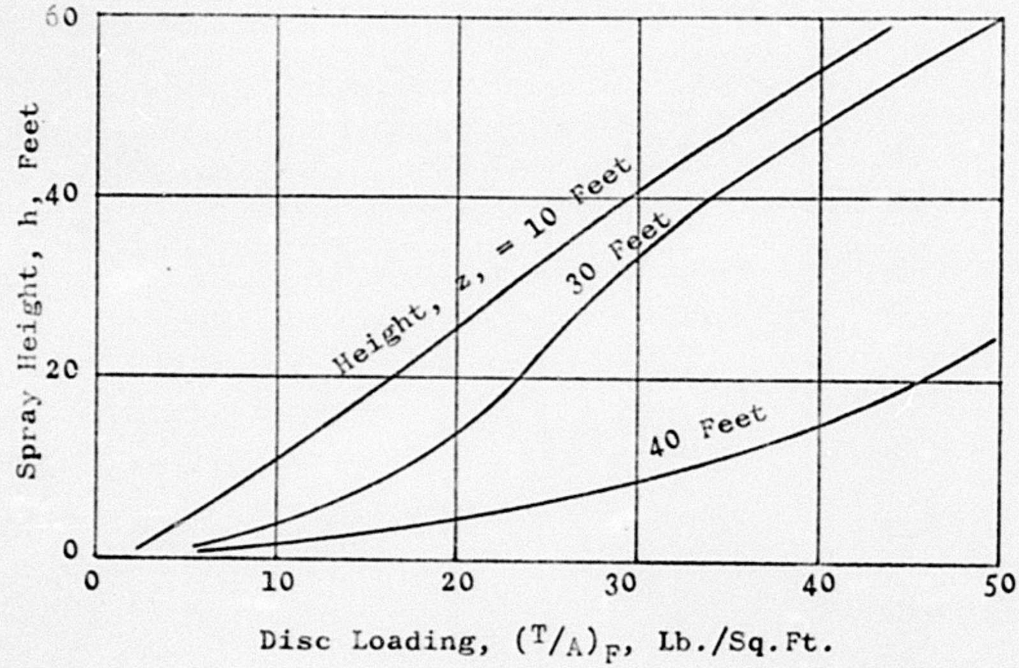
c) Height At Which Spray Was Observed For Various Disc Loadings

FIG. 14 X-19 MODEL TEST RESULTS

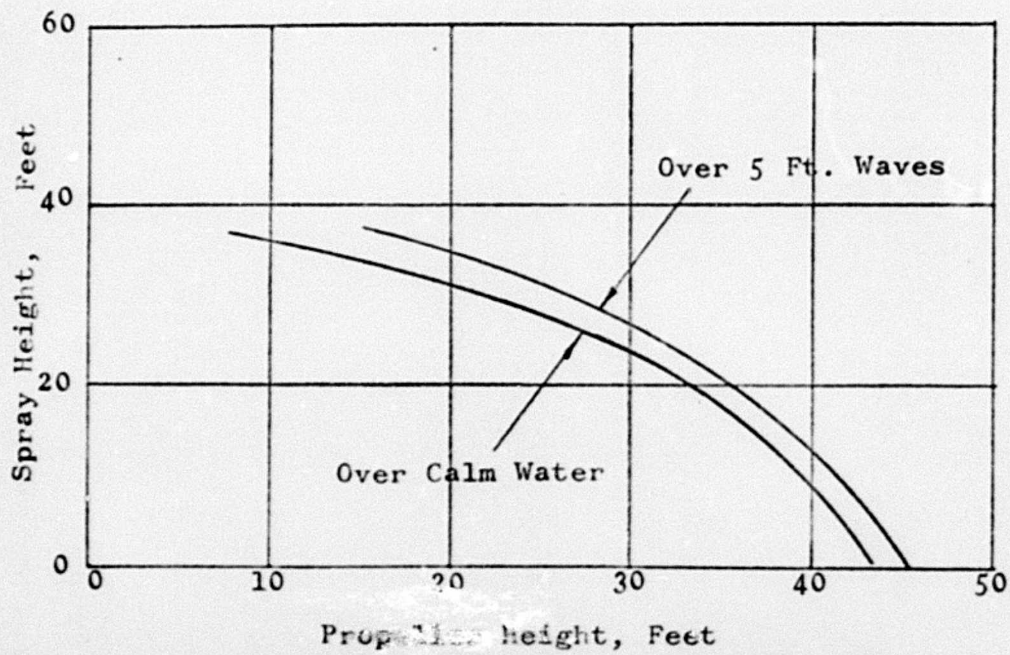


c) HEIGHT AT WHICH SPRAY WAS OBSERVED FOR VARIOUS DISC LOADINGS (OVER WAVES)

FIG. 14 CONCLUDED

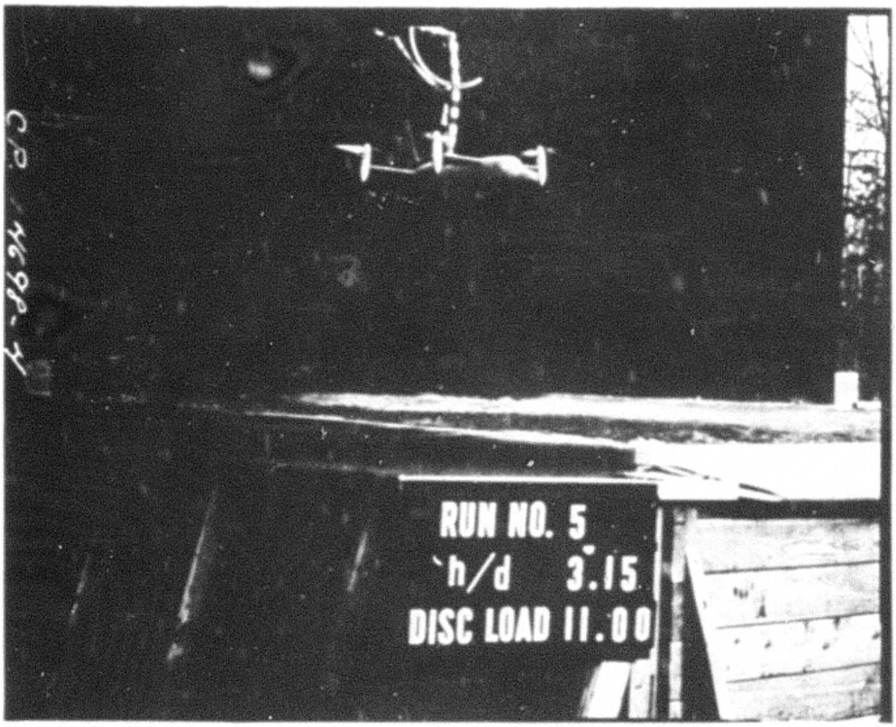


a) <u>Spray Height At Varying Disc Loading</u>
(calm water)

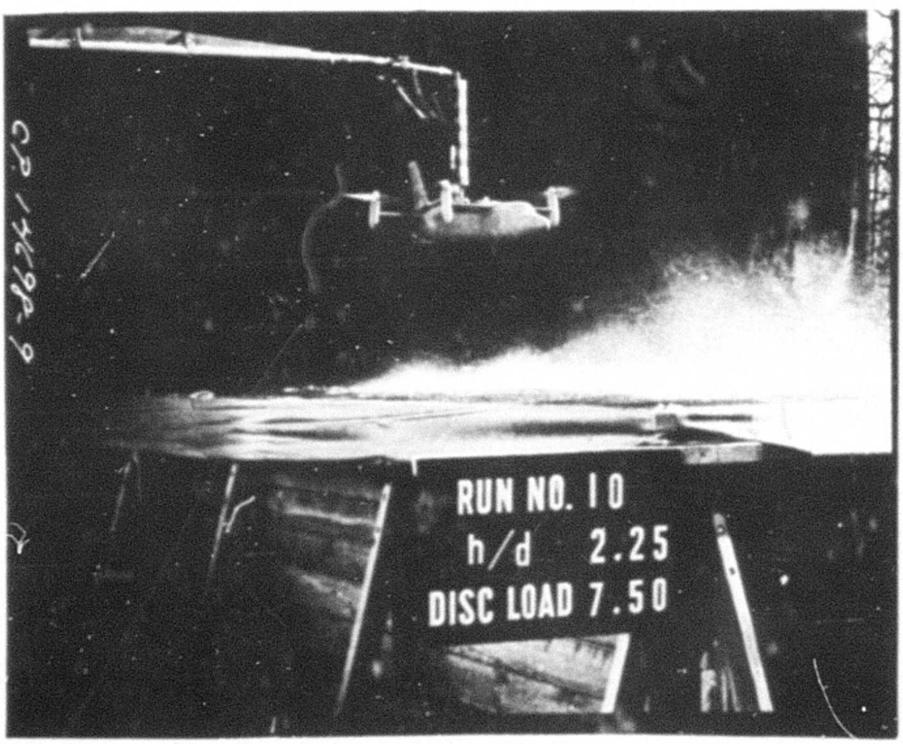


b) <u>Spray Height At 25.5 Lb./Sq.Ft. Disc Loading</u>

<u>FIG. 15 SPRAY HEIGHT FOR FULL SCALE X-19</u>

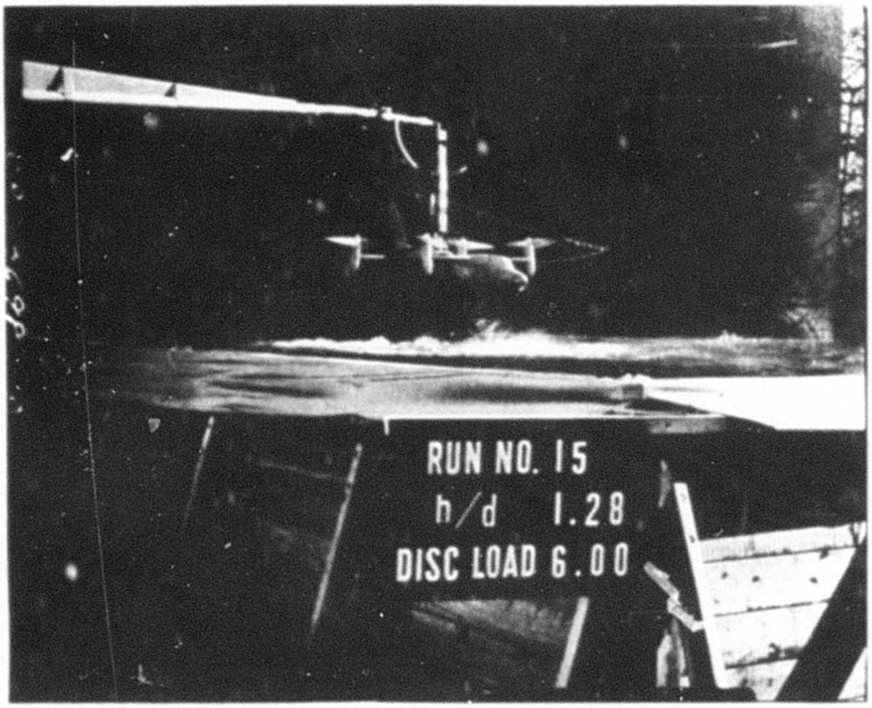


a) Full Scale Height 41 Ft.
Full Scale Disc Loading 70 Lb./Sq.Ft.

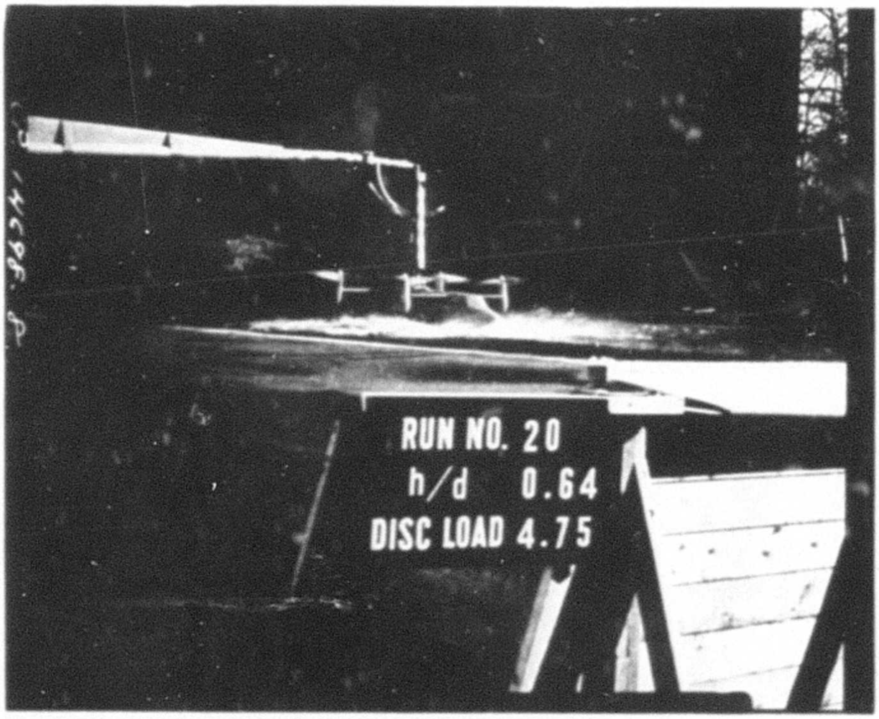


b) Full Scale Height 29.3 Ft.
Full Scale Disc Loading 46 Lb./Sq.Ft.

FIG. 16 X-10 MODEL TESTS

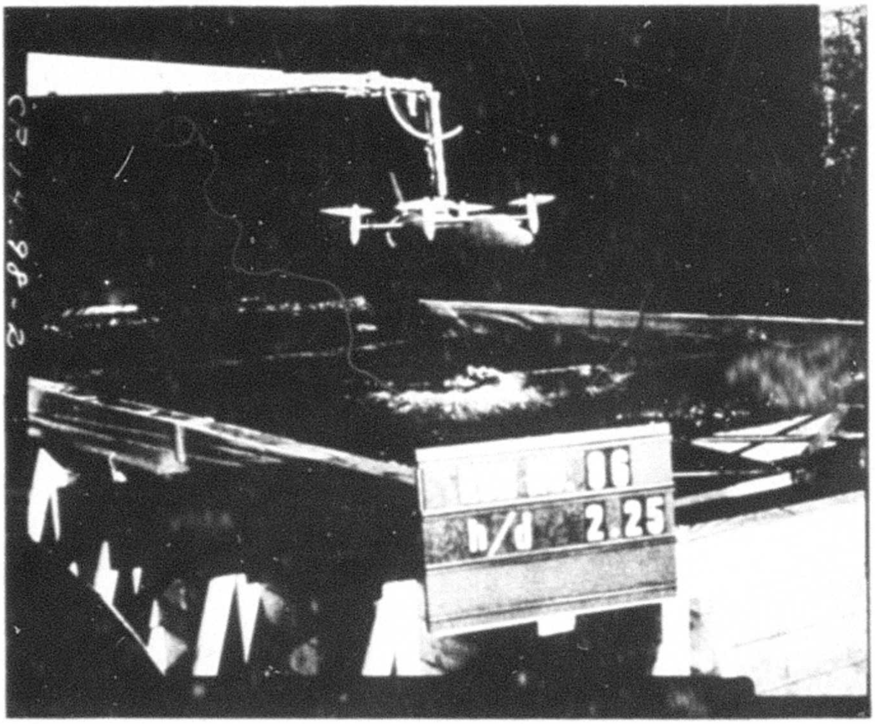


c) Full Scale Height 16.6 Ft.
Full Scale Disc Loading 37.5 Lb./Sq.Ft.

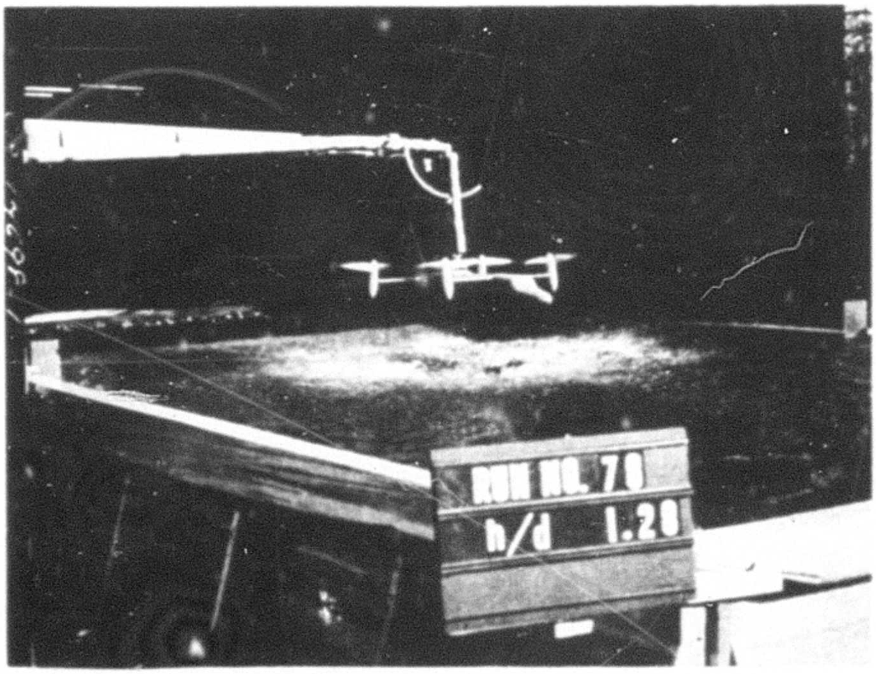


d) Full Scale Height 8.3 Ft.
Full Scale Disc Loading 30 Lb./Sq.Ft.

FIG. 16 CONCLUDED



a) Full Scale Height 29.3 Ft.
Full Scale Disc Loading 30 Lb./Sq.Ft. Front, 20 Lb./Sq.Ft. Rear



d) Full Scale Height 16.6 Ft.
Full Scale Disc Loading 30 Lb./Sq.Ft. Front, 20 Lb./Sq. Ft. Rear

FIG. 17 X-19 MODEL TESTS WITH FOUR MAN LIFE RAFT

MOTION PICTURE COMMENTS

An edited motion picture record of selected test runs is available as a supplement to this report.

The film sequences are arranged in groups representing the X-100 and X-19 configurations at simulated full scale disc loadings. The full scale loadings shown on the film are nominal values for any group of test runs, the true full scale disc loadings being within ± 3 lb./sq.ft. of the nominal value as shown in the tables below.

X-100 Tests

Run No.	z/D	Model Disc Loading $(T/A)_M$, Lb./Sq.Ft.	Full Scale Disc Loading $(T/A)_F$, Lb./Sq.Ft.	Nominal Full Scale Disc Loading On Film, Lb./Sq.Ft.
2	3.21	6.0	23.7	
6	2.25	6.0	25.5	26.0
12	1.28	6.0	27.1	
18	0.51	6.0	27.9	
3	3.21	7.5	33.3	
7	2.25	7.5	35.1	36.0
13	1.28	7.5	36.8	
19	0.51	7.5	37.6	
4	3.21	9.15	44.0	
8	2.25	9.15	45.6	46.0
14	1.28	9.15	47.3	
20	0.51	9.15	48.1	

X-19 Tests

Run No.	$^z/_D$	Model Disc Loading $(T/A)_M$, Lb./Sq.Ft.	Full Scale Disc Loading $(T/A)_F$, Lb.Sq.Ft.	Nominal full scale disc loading on film, Lb./Sq.Ft.
2, 41	3.15	4.75	18.6	20.0
8, 47	2.25	4.75	23.0	
13, 52	1.28	3.65	18.3	
19	0.64	3.65	21.0	
3, 42	3.15	6.0	29.0	30.0
9, 48	2.25	6.0	33.5	
14, 53	1.28	4.75	27.5	
20	0.64	4.75	30.0	
4, 43	3.15	7.50	41.5	40.0
15, 54	1.28	6.0	38.0	
21	0.64	6.0	40.5	
10, 49	2.25	7.50	46.0	50.0
16, 55	1.28	7.50	50.3	
22	0.64	7.50	52.7	
5, 44	3.15	11.0	70.5	70.0-80.0
11, 50	2.25	11.0	75.0	
17, 56	1.28	11.0	79.5	
23	0.64	11.0	82.0	

It will be noticed that in some of the above groups for approximately constant full scale disc loading, the model disc loading changes with height of the propeller. This is due to the variation of $(^T/A)_o$ with $^z/_D$ shown in the report.

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2. Kuhn R. E, Carter A. W. and Schade R. O., Over Water Aspects Of Ground-Effect Vehicles, IAS Paper Number 60-14, January 1960.

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4. Dewey D. B. and Byrne J. T., Application Of The Vertical-Float Concept To A 1/20 Scale PBM-5 Seaplane, General Dynamics/Convair Report GDC-63-064, March 1963.

5. Handler E. H., Tilt, Naval Aviation News p.p. 26-28, January 1964.